rogram and Abstracts

ENEFICIAL CO-UTILIZATION OF AGRICULTURAL MUNICIPAL AND INDUSTRIAL BY-PRODUCTS

Agricultural Research Service
U.S. Department of Agriculture

Beltsville, Maryland
May 4-8, 1997

BELTSVILLE SYMPOSIUM XXII

McConnell, L. L., editor. 1997. Program and Abstracts, Beneficial Co-Utilization of Agricultural, Municipal and Industrial By-Products, May 4-8, 1997, Beltsville Symposium XXII, U.S. Department of Agriculture, Agricultural Research Service, Beltsville, MD

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United States Department of Agriculture
Agricultural Research Service
Beltsville Area
Beltsville Agricultural Research Center
Beltsville, Maryland 20705

Welcome to Symposium Participants

The subject of this year's Beltsville Symposium concerns issues that are important to a vast number of agricultural producers, food and fiber processors, and land managers as well as to most cities, towns, and communities in the nation, and an increasing number of industries. The capacity to recover and utilize the wide range of organic and inorganic by-products generated by human activities is widely acknowledged as a key element in sustainable development nationally and internationally. With the approach of the 21st century, U. S. agricultural research programs are committed to supporting long-term sustainability of the Nation's food and fiber production systems. There is broad-based acceptance that this sustainability will result not only from the continued profitability of farming and ranching, but also through production systems that protect the environment. Co-utilization of organic and inorganic by-products can enhance the value and utility of materials that society no longer has the luxury of simply discarding. Resource conservation, environmental health and protection, and economic efficiency and competitiveness compel the development of innovative technologies and practices for recovery and beneficial utilization of these materials in holistic agricultural systems.

The purpose of Beltsville Symposium XXII is to examine the current state-of-knowledge, technologies, practices, regulations, incentives, benefits, and the potential for co-utilization of these by-products in agriculture, horticulture, and land management. The session discussions will be followed up with evening open panel forums and poster sessions on specific topics. The outcome of this Symposium should stimulate new and expanded collaborations and partnerships between the research community and agricultural producers, land managers, industry, regulators, and entrepreneurs. We welcome your participation in the research and development of innovative uses of these by-products.

K. Darwin Murrell

K. Darwin Murrell
Director
Beltsville Area

ACKNOWLEDGMENTS

The Friends of Agricultural Research - Beltsville (FAR-B), Inc., are cosponsors of the Beltsville Symposium series. FAR-B is a nonprofit group dedicated to supporting the research and educational programs at the Beltsville Agricultural Research Center. Membership is made up of former and current employees and a growing number of industry supporters. The Beltsville Symposium XXII Committee thanks the members of FAR-B for their many contributions to this symposium. In addition to FAR-B, Inc., the Beltsville Symposium XXII Organizing Committee also expresses its appreciation to the Agricultural Research Service

We are extremely grateful to the following organizations that provided financial contributions in support of the Symposium:

Wheelabrator - BioGro. Inc.
American Coal Ash Association
National Aggregates Association

Symposium Co-chairs:

Ronald F. Korcak, Plant Sciences Institute
Patricia D. Millner, Soil Microbial Systems Laboratory
Robert J. Wright, Environmental Chemistry Laboratory

Symposium Committee Chairs:

Program: Rufus L. Chaney, Environmental Chemistry Laboratory
Posters: Lawrence J. Sikora, Soil Microbial Systems Laboratory
Abstracts: Laura L. McConnell, Environmental Chemistry Laboratory
Proceedings: Sally Brown, Environmental Chemistry Laboratory
Budget: Albert E. Herner, Environmental Chemistry Laboratory
Local Arrangements: Tim Badger, Farm Operations Branch; Sally Reynolds, Soil Microbial Systems Laboratory; Charlotte Schomburg, Environmental Chemistry Laboratory; Cecil Tester, Soil Microbial Systems Laboratory
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PREVIOUS BELTSVILLE SYMPOSIA

1976	Virology in Agriculture
1977	Biosystematics in Agriculture
1978	Animal Reproduction
1979	Human Nutrition Research
1980	Biological Control in Crop Production
1981	Strategies of Plant Reproduction
1982	Genetic Engineering: Applications to Agriculture
1983	Agricultural Chemical of the Future
1984	Frontiers of Membrane Research
1985	Biotechnology for Solving Agricultural Problems
1986	Research Instrumentation for the 21st Century
1987	Biomechanisms Regulating Growth and Development: Keys to Progress
1988	Biotic Diversity and Germplasm Preservation - Global Imperatives
1989	The Rhizosphere and Plant Growth
1990	Remote Sensing for Agriculture
1991	Photomorphogenesis in Plants: Emerging Strategies for Crop Improvement
1992	Agricultural Water Quality Priorities
1993	Pest Management: Biologically Based Technologies
1994	Advances in Human Energy Metabolism
1995	Biotechnology's Role in the Genetic Improvement of Farm Animals
1996	Global Genetic Resources - Access, Ownership, and Intellectual Property Rights

FAR-B DISTINGUISHED SCIENTIST AWARD

Lawrence J. Sikora

Dr. Lawrence J. Sikora joined the Biological Waste Management and Soil Nitrogen Laboratory of the U.S. Department of Agriculture, Agricultural Research Service in 1975. Over his research career he has increased knowledge, developed technology and solved problems in the areas of treatment, use and disposal of municipal, animal and industrial residues. Dr. Sikora is recognized as an international expert in land application of organic by-products, transformations and movement of by-product constituents in soil, and biochemistry and microbiology of composting.

Dr. Sikora designed, fabricated and field tested a successful denitrification system for treatment of septic tank effluent using methanol as an energy source. His system is currently being used as an alternative on-site treatment system in several locations in the U.S. He demonstrated that disposal of municipal biosolids in trenches did not result in elevated heavy metal levels in crops grown on the site two years after disposal. As a result of this work the USEPA recognized entrenchment as an alternative means of safe disposal of municipal biosolids.

Dr. Sikora has made several significant contributions to composting and the safe and effective use of composts in agricultural systems. He developed and used a self-heating laboratory composter to determine optimum conditions for stabilization of organic matter, destruction of pathogens and oxidation of xenobiotics. His work on composting was a key part of the development of the Aerated Static Pile composting technology which has been adopted by hundreds of cities and many industrial firms. Dr. Sikora has developed methods to predict carbon and nitrogen mineralization rates and availability of phosphorus from municipal biosolids in the first year and in subsequent years after land application. This information has allowed states to develop guidelines for land application of municipal biosolid composts.

Dr. Sikora has developed methods for successful co-composting of municipal, animal and industrial by-products. His co-utilization approach has the potential to create more valuable products for agricultural and horticultural uses while contributing to the solution of by-product disposal issues. Dr. Sikora is frequently asked to transfer his research accomplishments to public and private sector groups and institutions. His input has contributed to the development of guidelines for land application of municipal biosolids, helped municipalities improve composting operations and resulted in a greater public understanding of benefits and risks associated with use of municipal, animal and industrial by-products.

GENERAL INFORMATION

Registration

Sunday	May 4, 4-8 PM	Holiday Inn, 10000 Baltimore Ave., Beltsville, MD
Monday	May 5, 7:30 AM-3 PM	Lobby, Bldg. 003, BARC West
Tuesday	May 6, 7:30 AM-3 PM	Lobby, Bldg. 003, BARC West
Wednesday	May 7, 7:30 AM-3 PM	Lobby, Bldg. 003, BARC West
Thursday	May 8, 7:30 AM-9 AM	Lobby, Bldg. 003, BARC West

Podium Presentations

All podium presentations will be given at the Beltsville Agricultural Research Center (BARC) in the auditorium of Building 003, BARC-West.

Poster Presentations

All posters will be displayed in the Grand Ballroom of the Holiday Inn. Posters may be set up any time after 7:00 AM on Monday, May 5. Authors must be present between 7:00 PM and 9:00 PM during their Poster Session on Monday or Tuesday, May 5 and 6.

Breakfast

Symposium registrants staying at the Holiday Inn are entitled to a complimentary buffet breakfast at the restaurant.

Slide Preview

Podium presenters can preview their slides in Room 232, Bldg. 003, BARC-West

Transportation from the Holiday Inn to Auditorium

Participants are expected to walk the short distance between the Holiday Inn and the auditorium in Building 003. Please see the map on the back inside cover of this program. For those who require assistance with transportation or in case of inclement weather, van transportation to Building 003 will be provided.

ARCEA Exhibit

The Agricultural Research Center Employees' Association (ARCEA) will have souvenirs available for purchase in the lobby of Bldg. 003

SCHEDULE OF EVENTS

SUNDAY, MAY 4

Registration, poster sessions, and the opening reception will be held at the Holiday Inn, 10000 Baltimore Ave. (U. S. 1 and Interstate 495), Beltsville, MD:

Registration	4-8 PM	Hallway in front of Grand Ballroom
Reception	6-9 PM	Grand Ballroom

MONDAY, MAY 5 (Auditorium, Bldg. 003, BARC-West)

SESSION I - CURRENT STATUS AND FUTURE CHALLENGES

Moderator: Michael Jawson, USDA-ARS - National Program Leader, Soil Biology

8:30 AM **Welcome**
K. D. Murrell, Director, Beltsville Area

8:35 AM **Introductory Remarks**
Richard Rominger, Deputy Secretary of Agriculture, Washington, DC

8:50 AM **FAR-B Distinguished Scientist Award**
Phillip C. Kearney, President FAR-B

9:00 AM **Why Co-Utilization?**
Ronald F. Korcak, USDA-ARS, Beltsville

9:30 AM **Why Compost?**
Lawrence J. Sikora, USDA-ARS, Beltsville

10:00 AM **Break**

10:30 AM **Status of Composting in America**
Nora Goldstein, BioCycle, Emmaus, PA

11:00 AM **Regulation of Beneficial Co-Utilization Products**
John Walker, USEPA, Washington, DC

Discussion

12:00 PM **Lunch - Bldg. 003, Rm. 020**

SESSION II - AGRONOMY OF BENEFICIAL CO-UTILIZATION

Moderator: J. Scott Angle - University of Maryland, College Park

1:00 PM **Agronomic Benefits of Agricultural, Municipal and Industrial By-Products: An Overview** - Jack Rechcigl, University of Florida, Ona

1:30 PM **Carbon and Nitrogen Minieralization during Co-Utilization of Biosolids and Composts** - John Gilmour, University of Arkansas, Fayetteville

1:50 PM **Nutrient Management Planning for Co-Utilization of Organic By-Products**
Lee W. Jacobs, Michigan State University, East Lansing

2:10 PM **Manganese Deficiency Induced by Lime-Rich Co-Utilization Products**
Sally Brown, USDA-ARS, Beltsville

2:30 PM **Break**

3:00 PM **Potential for Utilizing Coal Combustion Residues in Co-Utilization Products**
K. Dale Ritchey, USDA-ARS, Beaver, WV

3:20 PM **Use of Fresh and Composted De-Inking Sludge in Horticulture Production**
Regis R. Simard, Agriculture and Agri-Food Canada, Saint-Foy, Quebec

Discussion

7:00 PM **Poster Session and Discussion**
Evaluation of Beneficial Co-Utilization - Session I
Moderator: Lawrence J. Sikora, USDA-ARS, Beltsville
Holiday Inn - Grand Ballroom (refreshments will be served)

Composting of Wetland Sediments Heavily Contaminated with Chlorinated Hydrocarbon Wastes - B. Barré and G. Breitenbeck, Louisiana State University, Baton Rouge

Comparison of Commercial Fertilizer and Organic Wastes on Soil Chemical, Physical, and Biological Properties - M. Brosius[1], G. Evanylo[1], J. B. Ristaino[2] and R. Bulluck[2], [1]Virginia Tech, Blacksburg, [2]North Carolina State University, Raleigh

Use of Papermill and Municipal Biosolids to Enhance Yields of Cotton Grown on a Droughty Soil - C. Coreil and G. Breitenbeck, Louisiana State University, Baton Rouge

Use of Ammoniated Sugarcane Milling Waste to Enhance *In Situ* Degradation of Spilled Crude Oil - B. Grace and G. Breitenbeck, Louisiana State University, Baton Rouge

Dehydration of Restaurant Food Wastes Produces a Nutritious Feedstuff for Use in Pig Diets - R. O. Myer, D. D. Johnson, K. K. Boswick, and J. H. Brendemuhl, University of Florida, Gainesville

Immature Composte as Potential Biological Weed Control Agent in Commercial Vegetable Production Systems - M. Ozores-Hampton[1], T. A. Obreza[1], P. J. Stoffella[2], D. A. Graetz[3], [1]Univ. of Florida, Immokalee, [2]Univ. of Florida, Ft. Pierce, [3]Univ. of Florida, Gainesville

Co-Composting Dairy Manures with Urban Residues to Reduce Volatile Nitrogen Loss and Produce a Value-Added Product - L. J. Sikora, R. Erdman, and N. K. Enkiri, USDA-ARS, Beltsville

Food Waste Composts with Slow-Release Nitrogen Value: The Bulking Agent is More than just Fluff - D. M. Sullivan[1], S. C. Fransen[2], A. I. Bary[2], and C. G. Cogger[2],[1] Oregon State Unversity, Corvallis, [2]Washington State University, Puyallup

TUESDAY, MAY 6

SESSION III - ENVIRONMENTAL CONSIDERATIONS

Moderator: Elliot Epstein - E&A Environmental Consultants, Inc., Canton, MA

8:00AM **Fate and Potential Effects of Trace Elements: Issues in Co-Utilization of By-Products -** James Ryan, USEPA, Cincinnati, OH

8:30AM **Fate and Potential Effects of Xenobiotics**
George A. O'Connor, University of Florida, Gainesville

9:00AM **Effects of Co-Utilization Products on Number, Diversity and Functions of Soil Microbial Populations -** Scott Angle, University of Maryland, College Park

9:50 AM **Co-Utilization of By-Products for Soil Improvement and Erosion Control**
Lloyd D. Norton, USDA-ARS, West Lafavette, IN

9:40AM **Break**

10:10 AM **Bioremediation of Toxic Organics Using Compost**
Michael A. Cole, University of Illinois, Urbana

10:30 AM **Composting of Hazardous Wastes and Hazardous Substances**
Kirk Brown, Texas A&M University, College Station

10:50 AM **Remediation of Metal-Contaminated Soils Using Tailor-Made Biosolids and Compost Co-Utilization Products** - Rufus Chaney, USDA-ARS, Beltsville

Discussion

12:00 PM **Lunch - Bldg. 003, Rm. 020**

SESSION IV - HORTICULTURAL UTILIZATION

Moderator: Harry Hoitink - Ohio State University, Wooster

1:00 PM **Microbial Effects on Environmental Health and Product Quality Aspects of Recovery and Co-Utilization of Bio-Mineral Products** - Patricia Millner, USDA-ARS, Beltsville

1:30 PM **Co-Utilization in the United Kingdom**
Robin Szmidt, Scottish Agricultural College, Auchincruive, Scotland

2:00 PM **Cost and Environmental Impacts in Nursery Operations**
Conrad A. Skimina, Monrovia Nursery, Azusa, CA

2:20 PM **Strategies for Identification and Evaluation of Co-Utilization By-Products in Horticulture** - Francis R. Gouin, University of Maryland, College Park

2:40 PM **Break**

3:10 PM **Suppressive Compost for Biocontrol of Soil Borne Plant Pathogens**
Yitzhak Hadar, Hebrew University of Jerusalem, Rehovot, Israel

3:30 PM **Using Compost Products in Vegetable Production**
Aziz Shiralipour, University of Florida, Gainesville

Discussion

7:00 PM **Poster Session and Discussion**
Evaluation of Beneficial Co-Utilization - Session II
Holiday Inn - Grand Ballroom (Refreshments will be served)
Moderator: Rufus L. Chaney, USDA-ARS, Beltsville

Agronomic Impact of High Rates of Phosphogypsum Applied to Bahiagrass Pasture on a Florida Spodosol Soil - I. S. Alcordo, J. E. Rechcigl, R.C. Littell, A. K. Alva, and C.E. Roessler, University of Florida, Ona

Soil Remineralization for Sustainable Vegetable Production
J. Campe[1], T. A. O'Brien[2] and A. V. Barker[3], [1]Remineralize the Earth, Inc., Northampton, MA, [2]University of Massachusetts, Amherst

The Influence of Silicates on the Availability of Phosphates
S. Catalano, Pacific Mineral Development PTY LTD, Innisfail, Queensland, Australia

Coal Combustion By-Products Associated with Coal Mining Interactive Forum - Y. Chugh[1], B. Sangunett[1], K. C. Vories[2], [1]Southern Illinois University, Carbondale, [2]USDI, Alton, IL

Effect of Surface Incorporated Coal Combustion By-Products on Exchangable Ca and Al in Subsoil - Urszula Kukier[1], William P. Miller[2] and Malcolm E. Sumner[2], [1]Institute of Soil Science and Plant Cultivation, Pulawy, Poland, [2]University of Georgia, Athens

The Effect of Powdered Rock on Growth and Mineral Content of Vegetables
D. H. Miller, Oberlin College, Oberlin, OH

Nitrogen Recovery by Bahiagrass Receiving Varying Application Rates of Pelletized Biosolids - R. M. Muchovej[1], J. E. Rechcigl[2], [1]University of Florida, Immokalee, [2]University of Florida, Ona

Loss of Plant Nutrients During Windrow Composting of Various Feedstocks
D. Schellinger and G. Breitenbeck, Louisianna State University, Baton Rouge

Recovery of Biosolids-Applied Heavy Metals Sixteen Years After Application
J.J. Sloan, R.H. Dowdy, and M.S. Dolan, USDA-ARS and University of Minnesota, St. Paul

WEDNESDAY, MAY 7

SESSION V - CO-UTILIZATION PRODUCT USES

Moderator: Robin Szmidt Scottish Agricultural College, Auchincruive, Scotland, UK

8:30 PM	**Beneficial Co-Utlization of Municipal, Industrial, and Agricultural By Products in the Forest Products Industry -** A.R. "Bob" Rubin, North Carolina State University, Raleigh
9:00 AM	**Meet the Need of He Who Purchases Your Product ... Not the Need of the By-Product You are Trying to Market** - Kathryn Kellogg Johnson, Kellogg Supply Inc., Carson, CA
9:30 AM	**Product Quality Standards and Testing Criteria for Co-Utilization Products** Phillip Leege, Proctor and Gamble, Cincinnati, OH
10:00 AM	**Break**
10:30 AM	**Tailoring Product Standards to Targeted Uses** Chuck Henry, University of Washington, Seattle
10:50 AM	**Co-Utilization of FGD and Organic By-Products for Mine Reclamation** Richard Stehouwer, Ohio State University, Wooster
11:00 AM	**Sustainable Soil, Water and Air Quality: Mankind's Ultimate Challenge and Opportunity in the 21st Century -** J. Pat Nicholson, N-VIRO, Toledo, OH
	Discussion
12:00 PM	**Lunch - Bldg. 003, Rm. 020**
1:00 PM	Tour of: 1. Washington Suburban Sanitary Commission's Biosolids Composting Facility (Site II) in nearby Montgomery County, MD (Bus transportation provided). 2. USDA-BARC Free-Stall Dairy and Manure Handling System (Bus) 3. USDA-BARC Composting and Research Facility (Bus) 4. USDA-BARC Soil Microbial Systems Lab (Walk) 5. National Agricultural Library (Walk)
6:30 PM	Cash Bar, Holiday Inn Grand Ballroom
7:15 PM	Symposium Banquet - Holiday Inn
8:10 PM	Introduction, Patricia Millner, USDA-ARS, Beltsville
8:15 PM	**Environmental Ethics and Agricultural Policy: Visions and Opportunities** Margaret Maxey, University of Texas, Austin

THURSDAY, MAY 8

SESSION VI - CO-UTILIZATION PRODUCTS

Moderator: Nora Goldstein, BioCycle, Emmanus, PA

8:30 AM	**The Economics of a Custom Manure Management Service** Christopher Lufkin, Kamps Wood Resources, Grand Rapids, MI
8:50 AM	**Production and Marketing of Potting and Landscape Soils Using Coal Combustion By-Products** - Frank Franciosi, RT Soil Science, Rock Mountain, NC
9:10 AM	**Team Approach Towards Co-Utilization** Bill Seekins, Maine Department of Agriculture, Augusta
9:40 AM	**An Overview of Cost-Effective Benefits of Sustainable Compost Technologies** - Rosalie Green, USEPA, Arlington, VA
10:00 AM	**Break**
10:30 AM	**National Research Council Committee Review of Using Biosoilids and Effluents in Food Production** - Robert Bastian, USEPA, Washington, DC
10:50 AM	**Summary and Consensus** Charles Cannon, Composting Council, Alexandria, VA.

PLATFORM PRESENTATION ABSTRACTS

BELTSVILLE SYMPOSIUM XXII

SESSION I - CURRENT STATUS AND FUTURE CHALLENGES

WHY CO-UTILIZATION?

Ronald F. Korcak, USDA-ARS, Plant Sciences Institute, Beltsville, MD

The land application of by-products from agricultural, industrial or municipal sources is certainly not a new phenomena. Wood ashes, manures, crop residues and even early food processing wastes such as oyster shells were applied to the land and, dependant upon site specifics, probably showed a beneficial response by the next crop. These positive responses then lead to agricultural practices which were continued over time. Today, with renewed interest in concepts such as sustainability, biodynamic farming, and resource conservation, the practice of land application of by-products continues.

However, a problem exists. This problem is concentration. We, society, have developed technologies for the production of food, fiber, energy and the whole gamut of consumer goods with little regard for the by-products that these technologies produce or the effects that the processes themselves have upon the environment. The concentration per se of resources such as manures, coal ashes, waste mineral fines from crushing rock, paper mill sludges, sewage sludges etc. is further complicated by economics. Even if an individual by-product has some intrinsic value, like the fertilizer value of manure or as a source of trace minerals like waste mineral fines, there is a finite albeit small radial area within which these materials can be transported and utilized economically. Thus, the stockpiles continue to get larger and research dollars are spent on better liners for land filling materials.

The concept of co-utilization is simply the blending, mixing and/or co-composting of two or more by-products in order to produce a value-added 'designer' material which can be beneficially utilized to solve an agricultural problem, remediate soils and/or fulfill a market niche.

There are numerous examples, many of which will be noted in the presentations throughout the next week, where materials that were once called wastes are being co-utilized as value-added products. The goal of this Symposium is then two-fold. First to identify areas where co-utilization is being practiced and to foster this utilization to better use our natural resource base. Second is to highlight where good science can be practiced in developing co-utilization products that will have a significant impact on our society at large.

WHY COMPOST?

Lawrence J. Sikora, USDA-ARS, Soil Microbial Systems Laboratory, Beltsville, MD

Composting is a treatment process that requires time, knowledge, experience, equipment and effort. The benefits of starting a composting process must be balanced against some detriments of the process and the product. Organic by-products or residuals that are difficult to store, apply to fields uniformly, are unstable or nonuniform are good candidates for composting. Examples are manures, biosolids and food processing residuals. These byproducts are produced daily but often cannot be used on a daily basis and therefore must be stored. Composting transforms manures for example to a drier, more uniform and biologically stable product with many uses other than land application. Composted manures as such have a greater value than untreated manures to the farmer or feedlot owner. Nonuniform materials such as yard trimmings are transformed by degradation and mixing during composting into homogeneous organic mulch. Wet materials such as biosolids become drier as composts and therefore more easily land applied. By-products that contain

human or plant pathogens are safer after the high temperature treatment of composting. Compost products generally have a higher carbon to nitrogen ratio than the original byproduct and therefore act as a slow release fertilizer.

Detriments of composting byproducts are cost, treatment period, final use of compost product, and environmental issues such as odors and dust. Some investment in equipment and site preparation is required or recommended. Composting is not a fast process and, depending upon technique, could take several weeks to achieve stable compost. Determination of a suitable market for the compost is critical to justify the extra effort in producing compost. Composting is a biological process that can result in significant odor generation if not managed properly. Slow release nature of nutrients in compost requires higher application rates than with the original byproduct to obtain the same plant response. Higher application rates require more material and more trips across the field than with the original byproduct.

Knowing the benefits of composting and composts and its drawbacks provide the generator of byproducts a better estimate of cost versus return for starting a composting process. Environmental regulations may govern the ultimate treatment and beneficial use of byproducts. Proper selection of byproducts to co-compost or use with composts can result in value-added products that can be marketed a great distance from its source.

STATUS OF COMPOSTING IN AMERICA

Nora Goldstein, BioCycle, Emmaus, PA

An overview of composting activity in the United States will be presented, using both data from BioCycle national surveys and case studies. The talk will begin with the results of BioCycle's recent State of Garbage in America survey, which shows the current number of landfills, landfill capacity and tip fees, the national recycling/composting and landfilling rate and the number of yard trimmings and source separated organics composting sites. This information will provide much of the background for what factors are driving the development of composting projects in the United States. Municipal, institutional, commercial, industrial and agricultural residuals will be covered. Other data to be presented include the current number of biosolids and MSW composting facilities as well as overall trends in the beneficial use of biosolids. Finally, there will be a brief discussion of developments with composting technologies.

REGULATION OF BENEFICIAL CO-UTILIZATION PRODUCTS

John Walker, USEPA, Office of Wastewater Management, Washington, DC

A carefully developed and implemented system for quality management should greatly facilitate the beneficial use of recyclable organic material such as biosolids. A quality management system (QMS) could help facilitate regulatory compliance and the management of nutrients and of nuisances like odor, dust and traffic. Such a system would help improve the protection of public health and the environment and lay the groundwork for enhanced public acceptance. A draft EPA vision of a stakeholder-based QMS for the recycling of biosolids will be described. The relationship of this system to quality management by ISO 9000 and 14000 will also be described. The envisioned system includes a code of good practices, provisions for voluntary adherence, and independent third party verification of participant adherence to the QMS. The envisioned code includes guidance for minimizing nuisances, managing nutrients and suggests training for adherence to the code. At a minimum, those adhering to the code of good practices would be compliant with applicable state

and Federal standards. Applicable Federal standards for the management of biosolids and other organic and inorganic recyclables are discussed.

The QMS must be both effective and affordable if it is to be successfully adopted and implemented by municipalities and practitioners and if it is accepted by the public as meaningful for assuring sound biosolids recycling practices. Public acceptance is expected to be contingent upon a basic level of state and Federal regulatory oversight and enforcement in addition to some form of verification by independent third parties that municipalities and practitioners are adhering to the QMS. While an effective system of enforcement would be needed, its role would be reduced through a positive impact of the QMS on regulatory compliance and environmentally friendly practices.

SESSION II - AGRONOMY AND BENEFICIAL CO-UTILIZATION

AGRONOMIC BENEFITS OF AGRICULTURAL, MUNICIPAL AND INDUSTRIAL BY-PRODUCTS: AN OVERVIEW

Jack Rechcigl, University of Florida, Institute of Food and Agricultural Sciences, Ona, FL

One of the major concerns of today is the question of what to do with the enormous amounts of wastes generated, whether of industrial, agricultural or societal origin, that clutter the land surface, pollute the precious water, kill the fish and create carcinogen-filled smog. It is only a matter of time before this concern may change into a different kind of an issue, i.e., "How can we benefit from these wastes?", "What can we make from these wastes?", or "Who should be the beneficiaries of these wastes?" In fact, our current concerns about wastes may reverse themselves to the point that people will start worrying about waste conservation.

Of all the sectors, agriculture provides undoubtably the best opportunity for the utilization of waste. A case in point are the fertilizers, which are indispensable ingredients for successful plant production. With the escalating costs of fertilizers and the concern about the effects of over fertilization on water quality, there has been a rekindled interest in using recycled wastes in lieu of commercial fertilizers. Using wastes in agriculture provides not only an economic resource of nutrients for farmers but may also help to ameliorate some of the potential environmental problems resulting from stock piling and over loading of landfills. This paper will present an overview of possible uses of various organic wastes (e.g. compost, municipal and animal) and inorganic by-products (fly ash, phosphogypsum, paper manufacturing wastes, etc.), as well as various combinations of these materials for farm production.

CARBON AND NITROGEN MINERALIZATION DURING CO-UTILIZATION OF BIOSOLIDS AND COMPOSTS

John Gilmour, University of Arkansas, Dale Bumpers College of Agriculture, Fayetteville, AR

There are many possible combinations of biosolids and composts that are useful in agricultural and urban markets. Assessing the mineralization of carbon and nitrogen for these combinations can be accomplished quickly and inexpensively using computer simulations. A computer simulation model, DECOMPOSITION, which can be used to this end is described. The model simulates field decomposition and N mineralization for biosolids and composts evaluated in laboratory studies (decomposition kinetics, organic-C, organic-N, inorganic-N) by applying correction factors for climatic and soil properties. Simulations are made for various mixtures of biosolids and composts where the goals of co-utilization include recycling nutrients, maintaining soil productivity, protecting the environment, and developing marketable products. The importance of relative biosolid and compost quality, relative biosolid and compost decomposability, application site soil and application site weather are emphasized.

NUTRIENT MANAGEMENT PLANNING FOR CO-UTILIZATION OF ORGANIC BY-PRODUCTS

Lee W. Jacobs, Michigan State University, Department of Crop and Soil Sciences, East Lansing, MI

A large quantity of organic by-products are generated in the U.S. annually. These organic materials include animal manure, sewage sludge and septage, municipal solid waste (particularly yard waste), food processing, industrial organics, and logging and wood manufacturing residues. Most of these materials contain low contents of nutrients, are of biological origin, and can be safely returned to the land resource, as a waste management alternative. As a low nutrient fertilizer, organic by-products can often be applied to cropland as a source of plant nutrients, if their distribution is not economically limited by the costs of transporting them to available land. Because they are organic in nature and decomposable, organic by-products can be a source of odor and flies if not managed properly.

The application of organic by-products to cropland as a source of nutrients requires good nutrient management to avoid excess additions that can cause nutrient imbalances, or increase the risk of polluting water resources. Excess NO_3-N can potentially contaminate groundwater and excess P can accumulate in surface soils, increasing the risk of non-point source losses of P to surface waters by runoff and/or erosion. To accomplish good nutrient management, organic by-products should be applied at agronomic rates that will provide adequate nutrients for crop growth, without causing environmental pollution.

To determine the agronomic rate for an application site, the fertilizer recommendations are needed for the crop that is to be grown. These recommendations will usually be based on the soil fertility test results, taking into account the expected crop yield, and will identify what additional quantities of nutrients are needed beyond what the soil can provide. The concentration of nutrients in an organic by-product must next be determined by sampling and analysis. Most often the content of the primary nutrients (i.e., N, P_2O_5 and K_2O) will be satisfactory. However, amounts of secondary and micronutrients can also be measured and credited against the fertilizer recommendations, when any of these other plant nutrients are being recommended, in addition to N-P-K.

Once the nutrient content of the organic by-product is known, the rate of application can be determined, based on the quantity of recommended nutrients. Since the by-product will not contain the exact combination of N-P-K needed for each crop-soil combination, the by-product nutrients will need to be supplemented by commercial fertilizers or another by-product. A number of management tools are available to assist with these calculations, including worksheets and computer programs. To complete the management of organic by-product nutrient additions, suitable applicators must then be used to apply the calculated rate in the field in a uniform manner. Recordkeeping is another recommended management practice to help accomplish the nutrient management plan.

In summary, agriculture can assist with waste management in our society and help U.S. citizens manage their by-product residuals in an environmentally responsible manner. To accomplish this, from a technical point-of-view, involves primarily good nutrient and odor management. However, the non-technical aspects of applying by-products to land, like education and public acceptability, must not be forgotten, so generators, potential users and the general public can gain a better understanding of land application as a waste management alternative.

MANGANESE DEFICIENCY INDUCED BY LIME RICH CO-UTILIZATION PRODUCTS

Sally Brown, USDA-ARS, Environmental Chemistry Laboratory, Beltsville, MD

Lime addition to biosolids during the wastewater treatment process controls odors, aids in dewatering and reduces pathogens. Pathogen reduction as a result of lime addition can be sufficient to meet PSRP (Process to Significantly Reduce Pathogens) standards set by EPA 503 regulations (USEPA, 1993). When used properly, lime stabilized biosolids will maintain soil pH as well as add nitrogen and other nutrients to soil for agronomic crops. However, under certain conditions (light-textured Coastal Plain soils which are prone to Mn deficiency) application of lime-treated biosolids has resulted in Mn deficiency in susceptible crops. Manganese deficiency is the result of several soil, plant and environmental factors and will not necessarily reoccur in the same field from year to year. However, deficiencies following biosolids applications, have occurred on long-term research plots as well as on farmer's fields. As a result of these deficiencies, the Maryland Department of the Environment is considering limiting the use of limed biosolids on susceptible soils to meet the lime requirement of the crop.

Research in our lab has identified many ways to alleviate these deficiencies. Field experiments have shown that the addition of 200 kg Mn ha^{-1} as $MnSO_4$ was sufficient to alleviate deficiency in wheat (*Triticum aestivum*) on long-term field plots. Foliar Mn spray was also able to correct deficiency. Addition of Mn to biosolids prior to land application was able to increase Mn concentration in diagnostic leaf of wheat on short-term field plots. Application of sulfur to farmer's fields was able to lower soil pH and eliminate deficiency. Variation in the Mn content of biosolids, in the lime content of the biosolids, as well as the difficulties in predicting when Mn deficiencies will occur, make addition of Mn to biosolids prior to land application an impractical alternative. All other identified solutions appear to be feasible. However, Biosolid applicators are meeting with resistance to these solutions from both extension and regulatory personnel. This is a case in point of what can happen when the agronomic implications of a treatment technology are not taken into account. The resulting problems between applicators and regulators may also be typical for use of a non traditional material.

POTENTIAL FOR UTILIZING COAL COMBUSTION RESIDUES IN CO-UTILIZATION PRODUCTS

K. D. Ritchey, M. A. Elrashidi, R. B. Clark, and V.C. Baligar, USDA-ARS, Appalachian Soil and Water Conservation Research Laboratory, Beaver, WV

A total of approximately 90 millions tons of coal combustion by-products are produced annually in the United States, consisting of 54 million tons of fly ash (solid particles removed from smoke), 15 million tons of bottom ash, 3 million tons of boiler slag, and 20 million tons of flue gas desulfurization (FGD) material. Markets for boiler slag are well developed, but 67% of bottom ash, 75% of fly ash and 92% of FGD residues are available for beneficial co-utilization.

Numerous opportunities for agricultural use of these materials have been identified. Fly ash (a very fine, relatively inert, dry powder consisting mostly of iron, aluminum, calcium, silicon and oxygen) provides a means of reducing the water content of wet mixtures, and also can provide a source of B and some other micronutrients. It is being used to improve the texture and water-holding capacity of potting mixtures and technogenic soils. Class C fly ash (produced from burning coal from the Western US) can have a calcium carbonate equivalency of up to 50% and can serve as a substitute for aglime. Mixtures of fly ash and sewage sludge produced an effective medium for growth of apple trees in Northern West Virginia, and mixtures of fly

ash and municipal compost produced an acceptable soil substitute for nurseries in Ohio.

FGD materials contain mainly calcium sulfate or calcium sulfite, and some unreacted alkaline sorbent. These products can be used as an aglime substitute, as a phosphorous insolubilizer for incorporation with animal manure for land application on environmentally sensitive watersheds where excess P occurs in run-off, as a source of Ca and S in potting mixtures, as an anti-sodicity agent for displacing sodium from certain degraded mine lands being treated with sawmill by-products and to improve subsoil root growth enhancement properties of surface-applied amendments. Fluidized bed combustion materials, which contain both ash and FGD components, can be used for similar purposes.

USE OF FRESH AND COMPOSTED DE-INKING SLUDGE IN HORTICULTURAL PRODUCTION

Regis R. Simard[1], R. Lalande[1], B. Gagnon[1], J. Coulombe[2], and S. Yelle[2], [1] Agriculture and Agri-Food Canada, Soils and Crops Research Centre, Sainte-Foy, Quebec, Canada, [2]Laval University, Horticultural Research Centre, Sainte-Foy, Quebec, Canada.

Paper mills generate over three hundred thousand tons of de-inking sludge in the province of Quebec, Canada. These residues have C/N and C/P ratios of respectively 200 and 500 and may benefit from composting or mixing with secondary sludge. This would reduce the risk of N and P immobilization and of further crop deficiencies. The raw de-inking sludge corrected for N was compared with composted sludge, a mixture of primary and secondary sludge and inorganic N on winter cabbage yields and biochemical properties of a Tilly loam (loamy-skeletal, frigid Typic Humaquod). The compost was made of de-inking sludge and chicken manure. Rates of 0, 15, 30 and 45 dry tons of the three organic materials were supplemented or not with rates of 0 to 235 kg N ha^{-1} as ammonium nitrate. Samples were taken from the 0-20 cm soil layer one month after planting. The mixed sludges resulted in 20 % larger total and marketable cabbage yields than all other treatments. Fresh sludge performed better than composts without inorganic N. Composted sludges had a synergetic effect with mineral N on cabbage yields at the highest inorganic N rates. Soil N was significantly increased by mixed sludges but not affected by fresh or composted sludge. The highest sap NO_3^- contents were also found in the mixed sludge treatments. The N and P contents of cabbage heads at harvest were linearly increased by mixed sludge addition. The Cu content was increased by primary sludge whereas the Zn, Mn, Fe and Cr tissue contents were increased by all sludges. The content of Ni and Cd was decreased by all sludges although high contents were associated with the 45 T ha^{-1} mixed sludge addition. A trend for increased soil acidic phosphatase activity was observed. Alkaline phosphatase activities were increased by fresh and mixed sludges whereas aryl-sulfatase was affected by fresh materials only. Urease was not affected by the treatments. The mixed sludges are of particular interest since they resulted in significant increased in cabbage yields and N and P uptake while improving soil quality. The fresh sludges need supplemental N whereas the compost should be viewed more as a soil ameliorant than a true nutrient source.

SESSION III - ENVIRONMENTAL CONSIDERATIONS

FATE AND POTENTIAL EFFECTS OF TRACE ELEMENTS: ISSUES IN CO-UTILIZATION OF BY-PRODUCTS

James Ryan and L. Taras Bryndzia, USEPA, National Risk Management Research Laboratory, Cincinnati, OH

The Clean Water Act Section 503 Rule utilized a risk assessment methodology reflecting logical pathway analysis of transfer of pollutants to soils, plants, animals, and humans for land application of sewage sludge. In this effort, the importance of matrix effects, what is being applied in addition to the element of concern, was a harsh lesson learned in understanding the fate and effects of trace elements in environmental systems. As such, it is an important logical starting point for consideration in co-utilization of agricultural, municipal and industrial by-products in agricultural systems. The importance of this concept will be illustrated by an examination of matrix effects on bioavailability and phytoavailability. Thus, it will focus our attention on what needs to be understood if attempts to co-utilize by-products from different sources are to succeed.

FATE AND POTENTIAL EFFECTS OF XENOBIOTICS

George A. O'Connor, University of Florida, Department of Soil Science, Gainesville, FL

Organic wastes, particularly municipal sewage sludge and composts, can be expected to contain varying amounts of literally thousands of potentially hazardous organics of anthropogenic origin. Fortunately, the concentrations of most such xenobiotics are low in modern sludges and composts. Processes affecting the dissipation of organic chemicals in the environment include adsorption/desorption, abiotic/biotic degradation, volatilization, plant uptake/metabolism, and leaching. Waste-borne xenobiotics are, of course, subject to these dissipation mechanisms, but some mechanisms are enhanced by the wastes themselves. Fate and risk assessment data for a variety of organics in waste-amended soils confirm the minimal risk of xenobiotics to the environment or to humans.

EFFECTS OF CO-UTILIZATION PRODUCTS ON NUMBER, DIVERSITY AND FUNCTION OF SOIL MICROBIAL POPULATIONS

J. Scott Angle, University of Maryland, Department of Natural Resource Sciences and Landscape Architecture, College Park, MD

The application of co-utilization products, especially biosolids contaminated with high concentrations of heavy metals, can potentially affect soil microbial populations. Co-utilization products contain a variety of materials. Organic matter and micro and macronutrients can all enhance the number and activity of microbes in soil. Alternatively, toxic organics, heavy metals and soluble salts can have a deleterious effect on number and activity. Some reports from Europe indicate that co-utilization product borne metals can reduce the number of beneficial microbes, including *Rhizobium*, diversity and metabolic activity of microbes present in metal-amended soil. Metal toxicity is believed to select for ineffective mutants of rhizobia that fix little or

no atmospheric nitrogen. Studies at the University of Maryland, College Park and Environmental Chemistry Laboratory, USDA, ARS, Beltsville have alternatively shown that many of these parameters are enhanced following application of co-utilization products to soil. Numbers of rhizobia capable of nodulating alfalfa and soybeans were increased following application of biosolids to soil. This was observed despite the fact that the metal content of the soil was high enough to produce visible signs of toxicity in the respective macrosymbiont. Rhizobia isolated from plants experiencing severe phytotoxicity were capable of fixing amounts of nitrogen comparable to rhizobia isolated from control nodules. Diversity of rhizobia isolated from co-utilization product treated soils was greater than that found in control soils. Enhanced diversity was observed using both serological analysis of rhizobial isolates and ERIC-PCR genetic fingerprints from whole soil extracts. We attribute enhanced diversity to the unequal distribution and exposure of metals to rhizobia in contaminated soil. When we examined survival of rhizobia and growth of white clover in chelate buffered nutrient solution, zinc and cadmium were found to be approximately ten times more toxic to the plant compared to the rhizobial microsymbiont. At zinc and cadmium activities where plants experienced severe phytotoxicity, most plants were well nodulated and the nodules were capable of fixing adequate amounts of nitrogen. The only metal related effect noted at phytotoxic concentrations was a delay in nodulation. Nodulation was typically delayed for 24 to 48 hours compared to control plants. Staining of young roots following inoculation revealed that it was the development of root hair that was delayed. Once root hairs were produced, nodulation was observed to proceed at a nominal rate. It is our belief that where adverse effects of biosolids on rhozobia were reported, effects were related to past reductions in soil pH. Numerous reports indicate that when soil pH declines below 5.5, rhizobia that survive lack capacity to fix atmospheric nitrogen. It is therefore our opinion, that unless metal loading rates to soil greatly exceed permissible levels, no adverse effects on rhizobia will occur.

CO-UTILIZATION OF BY-PRODUCTS FOR SOIL IMPROVEMENT AND EROSION CONTROL

Lloyd Norton[1] , Roberto Altieri[2] and Cliff Johnston[2]
[1]USDA-ARS, National Soil Erosion Research Laboratory, West Lafayette, IN, [2]Department of Agronomy, Purdue University, West Lafayette, IN

Agriculture has been practiced in this country for hundreds of years. The general trend has been to produce foodstuffs and send them to towns and villages where most of the population lives. As a largely agrarian society, concentration of wastes was not a big problem because much of the wastes produced were applied back to the land where it came. With the population shift from farms to large cities the waste streams became larger and more concentrated. Disposal of these wastes were generally in landfills. Today with the increased cost of landfilling, less landfill space and regulations restricting what can be filled, land application of many waste streams is becoming more economically desirable. Also given the fact that many of these waste streams contain beneficial organic materials and nutrients that came from the soil to begin with, it may be beneficial to amend the soil with them to improve soil organic carbon content, nutrient status and control erosion. We studied two waste streams from a coal-fired power plant and a pharmaceutical operation in order to develop a co-blending technology. By combining the organic rich industrial sludge (ORIS) with fly and bottom ash from a fluidized bed combustor we were able to reduce adverse properties of both materials and create a soil like material with favorable properties. The impact of this research is that two waste materials with adverse properties can be combined such that they form a beneficial material with better properties than each individually with potential for erosion control.

BIOREMEDIATION OF TOXIC ORGANICS USING COMPOST

Michael A. Cole, Univ. of Illinois, Department of Natural Resources and Environmental Sciences, Urbana, IL

As a result of accidents, leakage, and inappropriate disposal of organic chemicals, there are numerous contaminated sites in the United States and other industrialized countries. In some cases, dispersal of these chemicals from the initial location poses a threat to human health and the environment. Remedial activities at such sites is necessary, but cost is often a limiting factor in the willingness of site owners to perform such activities. A substantial body of laboratory and greenhouse research--most of which was conducted within the past five years--indicates that a wide range of aliphatic and aromatic organic compounds are destroyed or detoxified during the composting process. Other work has demonstrated that mature compost, when added to contaminated soil, greatly accelerates biodegradation in comparison to soil without compost and that compost enhances plant establishment. In the latter case, the compost acts as a facilitating agent for phytoremediation, as well as promoting degradation by soil and compost microorganisms. Taken as a group, the available research strongly suggests that use of the composting process or mature compost will be a rapid, effective, and relatively inexpensive solution for detoxification of numerous organic contaminants in soil. The available literature will be reviewed and potential applications for field-scale remediation using compost will be proposed.

COMPOSTING OF HAZARDOUS WASTES AND HAZARDOUS SUBSTANCES

Kirk Brown, Texas A&M University, Department of Soil and Crop Sciences, College Station, TX

Composting has typically been used to treat agricultural wastes, yard wastes and sewage sludges which most often contain negligible concentrations of hazardous organic substances. Other wastes including household refuse, industrial wastes and hazardous wastes often contain greater concentrations of hazardous organic substances, some of which may be amenable to treatment by composting. Research has been conducted on the fate of volatile organic chemicals found in municipal and hazardous wastes, and the fate of polynuclear aromatics, petroleum, explosives, and pesticides during composting.

Volatile organic chemicals are rapidly lost during the initial 48 hours of composting both in aerated static pile and in-vessel composting systems. In-vessel composting has been shown to be effective in degrading 65-83% of nitrocellulose propellants in a 6-8 week period. This resulted in first order half lives of 7.7-13.6 days for the nitrocellulose. In-vessel composting of hazardous American Petroleum Institute separator sludge wastes (K051) resulted in the rapid loss of volatile organic chemicals including ethylbenzene, m-xylene, and dimethylnaphthalene. It also resulted in the biodegradation of anthracene, chrysene and phenanthrene. Detailed information on the observed volatilization rates and half lives during composting will be presented.

REMEDIATION OF METAL-CONTAMINATED SOILS USING TAILOR-MADE BIOSOLIDS AND COMPOST CO-UTILIZATION PRODUCTS

Rufus L. Chaney[1], Sally L. Brown[1], Judith G. Hallfrisch[1] Thomasz Stuczynski[2] and Harry Compton[3].
[1]USDA-ARS, Environmental Chemistry Lab, Beltsville, MD; [2]Inst. Soil Fertility and Plant Cultivation, Pulawy, Poland; [3]US-EPA, Emergency Response Team, Edison, NJ

Metal contamination of soils poses a variety of environmental risks requiring remediation under Superfund or Brownfield legislation. In cases of severe contamination and acidity, soils may be so Zn phytotoxic that plants cannot grow, and devoid of flora and fauna. Barren soil is easily eroded by water and wind, and metals are dispersed. In addition, windblown soil dust can enter houses and allow direct ingestion of soil by infants. Erosion produces a severely infertile soil that is incapable of supporting plant life due to severe P and N deficiency. Any *in situ* remediation effort needs to accomplish two goals: to remediate the toxicity of the contaminated soils (correct phytotoxicity and infertility), and reduce the danger from soil/dust metals by changing soil metals speciation to inert forms.

Surface application of high quality (low metal) biosolids mixed with liming materials (often fly ash by-products) has been used effectively to revegetate severely phytotoxic mine and smelter wastes in Palmerton, PA and Katowice, Poland. The combination of biosolids and fly ash in Palmerton was sufficient to reestablish a vegetative cover on soil that contained up to 50,000 mg Zn/kg. The Zn/Pb-smelter slag (rich in Zn, Pb, Cd, and As) at Katowice had been barren for over 50 years but grasses and legumes now thrive and are low enough in metal concentrations that they could be used as livestock feed.

Application of Fe and P-rich biosolids, in combination with $Ca(OH)_2$ and $CaCO_3$ supported revegetation by: 1) increasing specific metal adsorption by the amended soils, due especially to amorphous Fe, Mn and Al hydrous oxides in biosolids; 2) making the soil calcareous from the added lime which limits Zn-phytoavailability; grass species also especially benefit from Fe fertilization in high Zn soils. Specific metal adsorption hastens formation of metal species with very low solubility and bioavailability. The high P in biosolids increases metal sorption by the oxides, and forces formation of highly insoluble lead phosphate minerals with very low bioavailability. Proof of the formation of amorphous Pb/Ca-phosphate species is problematic, but new spectroscopic methods may demonstrate the Pb chemical species present and feeding studies have shown the reduction in Pb bioavailability. $Ca(OH)_2$ was required to raise soil pH because high soil Zn inhibited reaction of agricultural limestone with soil acidity. The result of biosolids applications was highly effective revegetation of these barren sites.

Biosolids are usually applied at rates to provide macro- and micro-nutrients and limestone for agronomic crops. On metal contaminated sites, higher rates of biosolid application may be needed to achieve the metal remediation goals; adding cellulosic materials to slow N release, or composting allows higher application rates needed for metal remediation. Many carbon sources can be used. Further, biosolids application can improve the water holding capacity of soils. This is particularly important for metal contaminated sites where severe soil erosion has occurred. Thus, application of limed-biosolids/composts supports remediation of metal contaminated sites by limiting the phytoavailability and bioavailability of soil metals, providing sufficient nutrients for plant growth, and improving the soil physical and biological properties. Progress in our research to demonstrate *in situ* remediation of soil metals by Tailor-Made Biosolids and Composts will be summarized.

SESSION IV - HORTICULTURAL UTILIZATION

MICROBIAL EFFECTS ON ENVIRONMENTAL HEALTH AND PRODUCT QUALITY ASPECTS OF RECOVERY AND CO-UTILIZATION OF BIO-MINERAL PRODUCTS

Patricia Millner, USDA-ARS, Soil Microbial Systems Laboratory, Beltsville, MD

The environmental and economic incentives to recycle and recover useful resources from various organic materials, such as animal manures, biosolids, landscape trimmings and food processing and marketing residuals, continue to increase. The same incentives are stimulating interest among scientists, horticulturists, entrepreneurs, and the minerals industries in the potential for utilization of various inorganic by-products, from cement, rock, aggregate, power plant and steel manufacturing operations, as beneficial additives to these organics. The resulting 'bio-mineral' products will provide stabilized organic materials augmented with mineral components useful in agriculture, horticulture, landscaping and reclamation. Some form of treatment will be required to remove pathogenic organisms that are present in primary organic constituents of such bio-mineral products. Existing federal standards ("40CFR503 for Code of Federal Regulations") for biosolids include criteria for assessing pathogen destruction achieved by several treatment processes. The applicability and appropriateness of these criteria to organic and bio-mineral products, not containing biosolids, will be discussed along with the need for test refinements appropriate to new technologies. Potential disease transmission pathways and case reports involving emerging pathogens, e.g., *E. coli* O157:H7, salmonellae, *Cryptosporidium parvum*, suggest that environmental health implications of farm and food production practices involving animal manure be reviewed and evaluated in a manner equivalent to that of biosolids. Specific information on pathogen survival and destruction relative to current and developing organics and bio-minerals recycling processes is needed to support development of guidelines for appropriate practices. Depending on the treatment process and the targetted mineral composition of the final product, inorganic constituents may be added prior to, during, or after organics processing. The sequence of mineral augmentation in organics processing has the potential to influence the quality of the product, but more research is urgently needed to optimize these benefits and to support recommendations that promote environmental and public health.

CO-UTILIZATION IN THE UNITED KINGDOM

Robin Szmidt, Scottish Agricultural College, Horticultural Advisory Service, Auchincruive, Scotland, UK

This paper will review utilization of co-composted materials from a UK and European perspective. In particular, the differing needs of the recycling/waste disposal industries and those of users of such products for horticulture will be considered.

In Europe, legislation demands adherence to specific guidelines covering land-use, effluent management, odour and transportation of wastes. Such factors may demand investment in relatively sophisticated technology. This includes adoption of enclosed systems for composting which will be broadly described. However, the market value of composted material and financial pressure on businesses and the public sector means that such investment may not be realistic. A computer 'model' to help optimise investment has been developed and can be used to predict the cost-benefit of different strategies. The economic factors are heavily influenced by the introduction of tax on landfill operations and it is predicted that this will increase the quantity of material which is co-composted. however this will have an impact on the market and on the quality of material available to horticultural industry.

Horticultural industry has readily adopted use of some co-composted materials, particularly in the landscape industries. However, for high value sectors, such as bedding plants and pot plants, adoption has

been slow. This should be put in perspective by comparing the enormous volume of research into peat-based growing media which has taken place in past decades with the relatively small investment in research into sustainable growing media such as co-composted materials.

This paper will assess trends in the literature which relate to horticultural use of co-composted material. In particular, the range of papers presented at a recent International Society for Horticultural Science (ISH) Symposium in Scotland will be reviewed and the conclusion of this meeting offered for discussion.

COST AND ENVIRONMENTAL IMPACTS IN NURSERY OPERATIONS

Conrad A. Skimina, Research Director Emeritus, Monrovia Nursery Company, Azusa, CA

Historically, nurseries have been co-utilizing organic wastes, such as sawdust, barks, mushroom composts and manure litters for a long time. Materials used now are sawdust, barks, poultry and stable litters, jute fiber, coconut coir, rice hulls, nut shells, yard wastes and bio-solids composts. Some manufacturers are re-using poly plastics from film and containers in making durable, plastic boards and laminates. With many states banning yard wastes from landfills, nurseries are utilizing this source of organic matter. A container nursery will generate about 60 yd^3 of waste/A/yr ($114 m^3 ha^{-1} yr^{-1}$.) After consideration of all operating costs in grinding their own green waste, a nursery can save approximately $7.83 per yard ($10.30 per m^3) of waste. This would require grinding 6,386 yd^3 (4861 m^3) of nursery waste to recover the cost of a $50,000 grinder, but the machine would stand idle for 96% of the time. Hindrances to utilization of own wastes are 1) cost of machinery, 2) maintenance of equipment, 3) lack of knowledge and 4) availability of an abundance of yard wastes from municipalities. In an experiment to find alternatives to methyl bromide, composts containing nursery wastes, were equal to or better than methyl bromide. The heat of composting eliminated the pathogens and weed seeds, and the resulting "suppressive" compost provided growth stimulation and biocontrol of diseases. In this experiment,. 51 out of 52 treatments were equal to or better than methyl bromide. Healthy composts can eliminate the use of fumigants and reduce the need of some fungicides.

STRATEGIES FOR IDENTIFICATION AND EVALUATION OF CO-UTILIZATION BY-PRODUCTS IN HORTICULTURE

Francis R. Gouin, Prof. Emeritus, University of Maryland College Park, MD

Ornamental horticultural industries utilize large quantities of organic matter and nutrients in the production, installation and maintenance of environmental plants. More than sixty percent of environmental plants marketed are grown in containers filled with rooting media containing fifty to seventy five percent organic amendments. The harvesting of field grown environmental plants removed between 200 and 250 tons per acre of top-soil resulting in rapid depletion of soil organic matter and productivity. Thus efficient production of these high valued crops requires intensive management and a constant supply of consistently uniform materials.

It is well recognized that environmental plants have diverse growth requirements, with regards to pH, soluble salts and water requirements. Some species can only be grown in rooting media with a pH near 5.0 and below while other perform best at pH's near 6.0 and greater. There are plants species capable of tolerating high levels of soluble salts in the rooting medium while other species are not capable of tolerating rooting media levels with a conductivity above 2.5 dS. There are some species of plants that can only be grown under

hydric conditions while other require arid conditions. Fortunately the majority of environmental plants perform best under normal irrigation regimes.

Success in co-utilization of by-products for the production of horticultural crops is dependent on satisfying the minimum requirements for the greatest number of species and identifying those species that have similar growth requirements. Growers cannot afford to formulate different rooting media for each species grown.

SUPPRESSIVE COMPOST FOR BIOCONTROL OF SOIL BORNE PLANT PATHOGENS

Yitzhak Hadar, Roni Cohen, Benny Chefetz and Yona Chen, Faculty of Agriculture, Food and Environmental Quality Sciences, The Hebrew University of Jerusalem, Rehovot, Israel

Composts produced from various agricultural wastes, such as, composted grape marc (CGM) and composted separated cattle manure (CSM), as well as composted municipal solid waste (MSW) have been studied for their suitability to suppress soil borne diseases. The nature and mechanisms of suppression as well as various specific examples are described here. Suppressive compost can be defined as providing an environment in which disease development is reduced, even when the pathogen is introduced in the presence of a susceptible plant. Plant disease suppression is a direct result of the activity of antagonistic microorganisms, which naturally recolonize compost during the cooling phase of the composting process. Thus, compost sterilization usually negates suppression. Although the mechanism of suppression is biological in all cases, different specific mechanisms were observed in relation to various plant diseases. The mechanisms involved in suppression of *Pythium aphanidermatum*, causing damping-off in cucumbers is of general nature. Competition for nutrients was found to be responsible for suppression and to be affected by carbon source concentration and microbial activity. Media amended with CGM , CSM or composted MSW were also effective in suppressing diseases caused by *Sclerotium rolfsii* and *Rhizoctonia solani*. The mechanism of suppression in this case is specific since mycoparasitism was observed. For example, S. *rolfsii* sclerotia lost their viability within 24 h of incubation in the compost. Scanning electron microscopy revealed that the sclerotia were heavily colonized by antagonistic fungi. In other composts high population of *Trichoderma* as well as antagonistic bacteria developed. Wilt in melons and cotton as well as crown rot in tomatoes caused by *Fusarium oxysporum* were also suppressed effectively by composts. The suppression of Fusarium is of great importance since fungicides are not available and the use of Methyl Bromide use is restricted. The use of suppressive compost provides effective biological control of plant pathogens. The use of mature compost is essential for this purpose and for healthy plant development in container media. It is therefore crucial to define parameters for determining maturity and use quality control measures for the application of compost in agriculture and horticulture. The key to large-scale utilization of disease suppressive compost is the development of reproducible products with defined and consistent properties.

USING COMPOST PRODUCTS IN VEGETABLE PRODUCTION

Aziz Shiralipour, University of Florida, Center for Biomass Programs, Gainesville, FL

Six compost types were utilized in some field experiments to grow broccoli (*Brassica oleracea botrytis*, var. !Brigadeer') and lettuce (*Lactuca sativa* var. 'Lallorosa') crops. The objectives of the field studies were twofold: to evaluate the effect of compost application on crop yields and the fate of the heavy metals and organic toxicants in plant tissues. The basic design of the site for each compost type was a replicated split plots with three rates of compost application (0, 37, 74 Mg ha^{-1}) as main plots and three supplemental nitrogen (N) rates (0, 34, and 68 Kg ha^{-1}) for subplots. Compost and N (from ammonium nitrate fertilizer) was added to the soil followed by planting crop seedlings. Prior to field experiments, greenhouse trials were conducted to determine the optimal rates of compost applications for these crops. Results of the studies suggested that the optimal rate of compost application for lettuce and broccoli was 37 to 74 Mg ha^{-1}.

The field test results indicated that significant lettuce yield increases can be obtained at compost application rates of 37 Mg ha^{-1} and 74 Mg ha^{-1} depending on the compost product. There may not be a significant increase in yields between applications of 37 Mg ha^{-1} and 74 Mg ha^{-1}. There was no significant interaction between compost and nitrogen for any of the six compost products and any of the four application rates (37 Mg ha^{-1} or 74 Mg ha^{-1} compost and 34, or 68 Kg ha^{-1} N) in terms of increased yields. There was a significant increase in broccoli yields at compost application rates of 37 Mg ha^{-1} and 74 Mg ha^{-1} compared to the control and between compost application rates of 37 Mg ha^{-1} and 74 Mg ha^{-1}. There was no significant interaction between compost and N application for five compost/nitrogen plot groups.

To remove barriers to compost acceptance, tissue analyses for the uptake of heavy metals and organic toxicants were performed on lettuce shoots and broccoli heads. In general, no significant relationship was found between the compost application and trace element content of the plant tissues. The organic toxicants present in some of the compost products were not detected either at all in plant tissues or in very low concentrations. In some cases, more organic toxicants were absorbed by the plants in the control plots (no compost) than by the plants in compost treated plots. No PCB could be detected in plants grown in control or compost treated plots.

Using three types of compost products to grow tomato and squash in South Florida, resulted in an increase in growth and yield of these vegetables with negligible increases in heavy metal concentrations in fruit. The negligible increases of some heavy metals in fruit were far below a hazardous level of human consumption.

These results clearly indicate that compost products which were used in these experiments can increase the yields of vegetable crops without increasing the concentrations of the heavy metals and organic toxicants to a hazardous level in plant tissues for human consumption.

SESSION V - CO-UTILIZATION PRODUCT USES

BENEFICIAL CO-UTILIZATION OF MUNICIPAL, INDUSTRIAL, AND AGRICULTURAL BY-PRODUCTS IN THE FOREST PRODUCTS INDUSTRY

A. R. Rubin, B.J. Frederick, T. F. Lyon, R.P. O'Dette, P.C. Steponkus, D. A. Freese, C. R. Campbell, J. Shelton, and G. G. Dramon, North Carolina State University, Raleigh, NC

The volumes of municipal, industrial, and agricultural or silvicultural byproducts generated as solid wastes or wastewater and biosolids generated during processing will continue to increase. In 1996, the estimated biosolids generation rate for the U.S. was 9.125 million dry tons and the estimated municipal solid waste generation rate in over 190.1 million tons of which 40% can be composted or converted to some beneficial reuse alternatives.

A comprehensive beneficial reuse or co-utilization program must contain several components if the program is to be successful. General issues which must be addresses include: 1) A state regulatory framework that encourages utilization. 2) Product testing and evaluation by institutions familiar to and trusted by the generators and the potential users. 3) Controlled demonstrations depicting proper product use and application onto forest lands or nurseries.

This paper addresses the development of co-utilization efforts in North Carolina. If there is a single key to the development of beneficial co-utilization efforts, that key is balance. The materials, by-products, or substrates blended and mixed as components of the co-utilization effort should act synergistically to add value to each of the materials recycled through the effort. The use of biosolids or composts as sources of essential nutrients, treated wastewater as an irrigation source, and wood ash as phosphorus, potassium, and calcium rich amendments on demonstration plots containing pine (pinus taeda) plantings improved plant biomass yield and tissue quality. Studies with wood ash, biosolids or animal manures, wastewater and construction /demolition/ disaster debris all indicate that the beneficial utilization of these material as single components of a reuse effort or as balanced components in a co-utilization effort enhance forest production yet impose minimal to nonexistent adverse impact on environmental quality. System designers have traditionally underestimated nutrient balances in forested systems. Biomass production does result when nutrient loadings of 400 lb-N balance with phosphorus loadings of 100 lb/ac potassium loadings of 200 lb/ac, and calcium loadings of between 200 and 500 lb/ac on test plantings in southern forests.

Cooperation between various state regulatory and service agencies, waste generator, public and private waste management service providers and the Land Grant University is vital to the success of any beneficial co-utilization effort. The potential for beneficial reuse has been demonstrated and opportunities abound for similar programs to promote biomass production on nursery, plantation, and natural forest stands.

INTRODUCTION OF TEST METHODS FOR THE EXAMINATION OF COMPOSTING AND COMPOST

Phillip B. Leege, Proctor and Gamble, Cincinnati, OH

The composting industry depends on sampling and analytical test methods borrowed from allied industry sources. These include assorted solid waste management, water and wastewater management, and the soil, peat, food, feed and fertilizer industries. Under these circumstances, it is not unusual for users to modify and adapt test methods to suit a variety of conditions. It is not unusual for differing interpretations of test results, to disagree application suitability, or to substitute one test for another even without demonstrated correlation among tests. A common set of standards for consistent testing by compost producers, marketers, users, researchers and regulators, and for their clients, doesn't exist.

The Composting Council's Standards and Practices Committee undertook a long-term project to develop a standard set of sampling and test methods for feedstocks, composting and compost. The initial phase of the project was in co-operation with the Minnesota Office of Environmental Assistance and the University of Minnesota Agricultural Extension Center Research Analytic Laboratory. The United States Department of Agriculture, Agricultural Research Service (ARS), Beltsville, MD has joined in the effort. Numerous other Agricultural Extension Centers and independent laboratories will become engaged during the introduction, peer review and acceptance process. The initial set of about 40 laboratory tests undertaken in Minnesota is expanding, along with sampling procedures, as other laboratories become involved.

The sampling and test methods being documented are suitable for several uses. Some methods are "quick tests" for composting process monitoring and control, and for approximation of product attributes. Other more rigorous and laborious tests are for regulatory safety and product marketing claims, and for marketing data.

The draft *Test Methods for the Examination of Composting and Compost"* is being released right now for introduction, familiarization and comments. Additional methods are welcome continuously. The next step will involve team evaluations of methods, and agreement. The USDA plans to follow this step with greenhouse and field testing to help evaluate different tests for the same compost attribute, and correlate compost attribute measurements to growth response. The concluding step is a proposed joint long-term effort with a recognized national standards-setting organization to standardize the protocols, and insure their vitality.

MEET THE NEED OF HE WHO PURCHASES YOUR PRODUCT...NOT THE NEED OF THE BY-PRODUCT YOU ARE TRYING TO MARKET

Kathryn Kellogg Johnson, Kellogg Supply Inc., Carson, CA

Co-Utilization, Beneficial Use, By-products, Waste products, Beneficial Co-Utilization Products, Whatever happened to soil conditioners, fertilizers, potting mixes, planting mixes, topdressing, canning mixes, ... etc. Are we speaking a different language?

Somehow we "beneficial use" types find it hard to take focus off of our unique set of problems in order to spend time in the world of those who could solve our problems by utilizing our finished products to correct and improve their growing conditions.

The strategy outlined in this presentation balances the interests of "making the waste product go away -inexpensively and fast" with searching for opportunities to marry organic feestocks that are available in an area with the problems they can solve in that same area.

Kellogg Supply has a history of transforming former waste products into successful commercial

products. Throughout 72 years we have blended various organic ingredients together and developed products which uniquely improved soil conditions and consequently growing conditions for our customers.

The abundance of available “by-products” supports the need to focus on manufacturing products that are tremendously useful to customers as opposed to manufacturing what makes the treatment facility operations run more smoothly. The two needs are not mutually exclusive, they often require a different mindset to solve both simultaneously.

TAILORING COMPOST STANDARDS TO TARGETED USES

Chuck Henry, University of Washington, School of Forest Resources, Seattle, WA

Potential compost uses are quite varied, ranging from potting mixtures to landfill cover, from a fertilizer to a fertilizer sink. Recent research strongly suggests that it is actually hard to manufacture a compost with concentrations of contaminants whose use is not protective of public health and the environment (an example study will be presented in this paper). Thus, "tailoring compost standards to targeted uses", at least from a "scientific viewpoint" must be approached from a marketing point of view.

The future of compost use lies in either heavy subsidy of the compost industry, in sustainable markets, or a combination of both. To a certain degree, this dictates the approach to compost standards, and subsequently to approaches in compost manufacturing. There may exist two philosophies: 1) make a product, then convince consumers to purchase, or 2) find out what the consumers want/need, then manufacture to their specifications. One can see the importance and different facets of compost standards in a Pacific Northwest example: The Mountains to Sound Greenway Restoration work. Here is a situation where a "landscape" quality product isn't necessarily needed (i.e., consistent size, color), but the handling will be by volunteers, so perception is important (smell, look, safety).

The scientist's role in compost standards remains important. Whereas, on a technical basis, rigorous additional research and risk assessment (as was performed for biosolids) may not be necessary, assuring that contaminants do not pose problems (i.e., the perception problem) may be. But, more importantly, documenting proper uses (avoiding excess N application or immobilization; immaturity causing odors or temporary phytotoxicity; salts), and documenting beneficial values of compost (especially economic returns), will be the scientists biggest contribution to compost standards and the future of composting.

CO-UTILIZATION OF FGD AND ORGANIC BY-PRODUCTS FOR MINE RECLAMATION

Richard C. Stehouwer, The Ohio State University, School of Natural Resources, Wooster, OH

Co-utilization of by-product materials in mine reclamation represents a potential double benefit to society because the materials are diverted from the solid waste stream and utilized to restore degraded landscapes. Several experiments have been conducted or are in progress to investigate minespoil amendment with flue gas desulfurization (FGD) by-products, yard waste compost, and sewage sludge as an alternative to resoiling in abandoned mined land reclamation. We found that interactions between these materials influenced the solubility and mobility of major labile elements in FGD (Ca, Mg, S) and in the spoil (Al, Fe), which in turn affected plant growth.

In all experiments co-application of FGD and organic by-products increased spoil pH and exchangeable Ca, Mg, and S, and decreased Al and Fe in the depth of incorporation. Application of either material alone produced similar effects, but of a smaller magnitude. Co-application of FGD and compost or sewage sludge had little effect on surface runoff water chemistry.

Movement of surface-applied materials into subjacent, unamended spoil produced several interactive effects which were not consistent in all experiments. Application of FGD by-products alone consistently increased Ca and Mg and decreased Al and Fe in subjacent spoil due to exchange reactions between these metals. Application of organic by-products alone and with FGD has had varied effects on subjacent spoil chemistry. In one greenhouse study, extensive leaching caused surface-applied compost to reduce subjacent exchangeable Al and Fe by 25 to 30% relative to an unamended spoil. With combined compost and FGD, however, subsurface increases in Ca and decreases in subsurface Al were larger than with either material alone. In a greenhouse experiment with much less leaching, FGD alone decreased subsurface Al and Fe, but combined FGD and compost increased subsurface Al and Fe. In a field experiment, six months after application of sewage sludge, exchangeable Al and Fe in the subjacent spoil were one to four times larger than in spoil covered with topsoil. With combined FGD and sewage sludge, however, subsurface reductions in Al and increases in Ca were greater than with FGD alone. On severely compacted spoil, however, co-application of FGD and compost caused large increases in soluble Al and Fe just below the depth of amendment incorporation which have persisted for 18 months. These varied results and interactive effects appear to be due to movement and complexation of metals by soluble organic ligands in the compost and sewage sludge. Another experiment showed transport of trace metals from FGD and sewage sludge amended spoil was highly correlated with soluble organic C concentrations. Apparently complexation of metals by these ligands increased their solubility and mobility in the spoil. The extent to which this occurred would be a function of several factors including the amount of soluble organic matter and FGD added, and chemical and hydraulic characteristics of the spoil profile.

In most experiments vegetative growth on acidic spoil was improved by combined amendment with FGD and organic by-products relative to either material alone. In two experiments, however, co-application decreased growth: in one case due to compost-induced N-immobilization, and in another reductions in plant growth may have been due to increased Al uptake.

Direct revegetation of minespoil through co-application of FGD and organic by-products is a possible alternative to reclamation with borrow topsoil. These experiments have shown that co-application has the potential to enhance amelioration of subsurface toxicity. Elucidation of the mechanisms by which this occurs would enable the development of co-utilization strategies which can maximize this beneficial effect.

SUSTAINABLE SOIL, WATER AND AIR QUALITY: MANKIND'S ULTIMATE CHALLENGE AND OPPORTUNITY IN THE 21ST CENTURY

J. Patrick Nicholson
Chief Executive Officer, N-VIRO International Corporation, Toledo, OH

The author discusses the idea that sustainable agriculture is a critical component of sustainable economic development in most industrial countries and in all Third World countries. It reviews how science and technology are our best ways of staying competitive and that science and technology, not political clout, must determine America's future agricultural, environmental and economic policies and programs. Technologies, such as composting and the N-VIRO Soil™ process that immobilize and stabilize organics and nutrients and provide "slow release" soil fertility through controlled mineralization, are discussed. The author feels technology transfer must be an essential component of the visionary bridge into the 21st Century. The bridge must be wide enough to allow environmental, agricultural and public communities to work together to do what is right. Political courage and leadership together with scientific are absolute vital components of that bridge structure. A sustainable national program of technology transfer is vital if such technologies are going to be understood, accepted and utilized. Examples of this could include: the requirement of guidelines for non-point source water pollution management practices in particular manures, biosolids, chemical fertilizers and pesticides and industrial organics. The Department of Transportation's "Transportation Research Board" program could be used as a model for the USDA and USEPA to provide a vehicle for technology transfer to public and private interests. The USDA and USEPA should be required to accept the challenge and the opportunity of sustainable soil, water, and air quality and form a joint commission with the White House Office of Environmental Quality, the Water Environment Federation and the Farm Bureau. Congress should be encouraged to establish that resource conservation and recovery is in the best interests of this country and that unnecessary disposal of natural resources is wrong.

The paper identifies that over 2.2 billion wet tons of animal manure is generated annually in the USA and generally mismanaged. Gases (methane, nitrous oxides and carbon dioxide) generated in waste organic (manures, food process wastes, and pulp and paper wastes) disposal facilities (landfills, lagoons and surface impoundments) exceed 20 trillion cubic feet per year, which is greater than all car and truck gases or two-thirds of all coal-fired electric utility gases. Yet these gases, run-offs and leachates are unregulated!

This paper is a review of the status of the United States and the rest of the World's governments' policies and practices with regard to the Earth's vital land, air and water resources.

SESSION VI - CO-UTILIZATION PRODUCTS

THE ECONOMICS OF A CUSTOM MANURE MANAGEMENT SERVICE

Christopher S. Lufkin[1] and Ted L. Loudon[2], [1]Division Manager, Kamps Wood Resources, Grand Rapids, MI; [2]Agricultural Engineering, Michigan State University, East Lansing, MI

The recently completed Michigan Manure Management Demonstration Project provided data and experience that were used to develop cost estimates for on-farm composting as a manure management option. These costs were compared to the costs of conventional manure management systems such as daily haul and liquid manure handling with long term storage. The comparison demonstrated composting to be favorable economically when compared to these manure management systems.

This paper will focus on the economic potential of operating a for-profit manure management service which produces compost. This service would contract with livestock producers who are interested in paying for the production of compost on the farm. Additionally, the service would provide the marketing and distribution of the finished product.

The paper will include evaluation of the economics and practicality of various carbon sources as amendments for on-farm composting. These will include ground waste wood, sawdust, leaves and farm grown carbon sources.

PRODUCTION AND MARKETING OF POTTING AND LANDSCAPE SOILS USING COAL COMBUSTION BY-PRODUCTS

Frank Franciosi, General Manager, RT Soil Sciences, Rocky Mount, NC

Gardening and landscaping are the number one leisure time activities in the US. During 1994, Americans spent over $25 billion on gardening and landscaping. In North Carolina alone, potting and landscaping soils are consumed at a rate of 2 million cubic yards each year according to a recent survey by North Carolina State University.

Coal combustion by-products (CCB's) can be used in the production of superb quality, compost based, synthetic soils. The process involves the composting of source separated organic materials that are by-products generated by agricultural and industrial operations. This natural biological process is optimized by using scientific techniques and current equipment technologies. CCB's can be used in many ways to improve the characteristics of these compost based soils. Fly ash may be used as a replacement for sand, providing water holding capacity as well as improved drainage characteristics. Flue gas desulfurization residues can be used as a source of elemental calcium and sulfur which are required by certain plant types. These potential benefits, as well as others , from CCB usage will be discussed. This paper will present scientific data demonstrating the advantages of compost/CCB blend soils in comparison to conventional potting and landscape soils. This paper will also describe some of the challenges in gaining regulatory approvals and market acceptance and the strategies employed to over come these barriers.

TEAM APPROACH TOWARDS CO-UTILIZATION

Bill Seekins, Maine Department of Agriculture, Food and Rural Resources, Maine Compost Team, Augusta, ME

The Maine Compost Team is a self-directed, inter agency team started in 1990. There are four permanent members on the team. Each team member has a specific role, reflecting the task of the agencies which employ them. Richard Verville, Extension Educator, the team organizer and project coordinator, develops the educational aspects of the projects. This includes videos of each demonstration. Geoff Hill, State Planning Office, works with municipalities on recycling and reuse issues. He provides the municipal contacts, knowledge of other programs, and related political considerations. Dr. Bill Seekins, Maine Department of Agriculture, works with agricultural industries to find solutions to solid waste management problems and is the technical advisor (or compost process troubleshooter). Mark King, Maine Department of Environmental Protection, is charged with licensing compost facilities and as part of that work, also provides a significant amount of technical assistance to site operators. The team also involves other agencies, such as the Natural Resources Conservation Service (formerly Soil Conservation Service) for siting help, and other Extension personnel.

The team has a mission, vision, and values statement as well as a plan of work. They have over the years been able to gauge the evolution of the compost industry and to plan what educational projects would be timely to advance composting knowledge. Their role is not to service existing projects, but instead to identify feedstocks, processes, equipment, and technologies that can move composting forward. By having worked together for five years, the team members work has a synergistic effect that benefits clients. Agency turf battles are avoided and individual strengths utilized and maximized. The team provides a single source of information and advice on composting avoiding conflicting information from different agencies.

All projects undertaken by the team must meet the following criteria: 1) it must have an educational component, 2) there is no higher or better use for that feedstock, 3) there is a financial basis that reflects the true costs of the operation, 4) operators/managers agree to follow the management guidelines developed by the team, and 5) it can be linked to others with feedstocks in that geographic area. The information gained is shared through technical papers, project videos, and conference/seminars with individuals, groups, or industries.

The team is now in its final phases of working with the University of Maine Cooperative Extension and the University of Maine to develop an on-going compost operator certification school for individuals throughout the eastern seaboard and the Canadian Maritimes. The first class of 15 students will graduate in the spring of 1997.

AN OVERVIEW OF COST-EFFECTIVE BENEFITS OF SUSTAINABLE COMPOST TECHNOLOGIES

Rosalie Green, USEPA, Arlington VA

Remediation of harmful wastes that are hazardous to health and/or damaging to the environment in contaminated soil water, and air is an industry that provides engineering, chemical, and physical processes from air stripping to combustion at high temperatures. Recent less costly methods to address toxic waste cleanup are biological processes from land farming organisms to compost, destruction/immobilization of pollutants, or in combination with other processes such as phytoremediation.

Since 1987, landfill bans on yard debris in 23 states have spurred an increase of compost facilities from 700 to about 4000 in 46 states. Reulations governing the siting, permitting, and operation of solid waste composting facilities exist in 25 states.

There are issues related to recycling, including compost, in the Executive Orders that require Federal agencies to Buy Recycled and set up Model programs that demonstrate closed-loop and sustainable use of our resources--including organic waste resources. About 70% of both municipal and rural solid waste is organic.

The applications of compost for soil bioremediation, either alone or in combination with phytoremediation, have been shown to degrade contaminants such as chlorinated hydrocarbons, volatile organic compounds, pesticides, petroleum products, wood preservatives, explosives and to immobilize mobile heavy metals. Tailored compost systems have been used cost effectively to collect and treat contaminants in storm water runoff above the 90% level. Mature compost has prevented soil erosion, suppressed plant disease, and destroyed wildlife habitat, wetland restoration, and agricultural soil infrastructure.

These compost technologies will be discussed and specific examples will be shown.

NATIONAL RESEARCH COUNCIL COMMITTEE REVIEW OF USING BIOSOLIDS AND EFFLUENTS IN FOOD CROP PRODUCTION

Robert Bastian, USEPA, Washington, DC

Potential health effects as well as lack of compliance with existing regulatory requirements are frequently raised as concerns when projects propose to recycle biosolids on farmland used for the production of food crops for direct human consumption. These concerns were a primary focus of the report, "Use of Reclaimed Water and Sludge in Food Crop Production," issued by the National Research Council/National Academy of Sciences in early 1996.

The three-year study was undertaken to help answer some of the questions that have been raised about the safety of crops grown in fields where treated municipal wastewater effluent or biosolids have been applied. It provides an independent assessment of the risks associated with these practices and provides recommendations for improving these recycling practices and their acceptance. The committee that conducted the study based its report on existing published literature and discussions with experts in the field. The study reviewed the current state of the practice, public health concerns, existing guidelines and regulations, and implementation issues. While the committee did not conduct a formal risk assessment of possible health effects, it did review the methods and procedures used by EPA in its extensive risk assessment which was the basis of the Part 503 rule.

The NRC report confirms the basis of Federal policy that properly treated and managed municipal wastewater effluents and biosolids can be safely and effectively used in food crop production, while presenting negligible risk to the crops, consumers, and the environment. To help address the persistent concerns regarding the potential for exposure to contaminants, nuisance problems and adequacy of oversight of programs involving agricultural use of biosolids, the report suggests that POTWs, private processors, distributors, and applicators should not only comply with all regulatory requirements and management practices, but also take extra steps to demonstrate such compliance to various stakeholders (e.g., neighbors, farmers, food processors, and consumers). It recommends full public participation, self-monitoring and reporting programs, and public education campaigns. The study report suggests that it is especially important that these public information efforts be continuing and detailed, as public awareness that safe practices are in fact being followed is necessary if monitoring by state or local entities is likely to be minimal.

SUMMARY AND CONSENSUS — WHERE DO WE GO FROM HERE?

Charles Cannon, Composting Council, Alexandria, VA.

Composting and beneficial use of many organic resources has become increasingly important in the last decade. Research on how to use composts most beneficially and to characterize the risk from marketed compost products has provided further evidence that the best choice for many of the agricultural, municipal, and industrial organic resources and by-products is composting for specific markets. Producing high quality mature compost products gives access to markets. The model encouraged by this meeting, that other by-products may be built into composts to make more beneficial and inherently safer compost products, is another step toward the goal of producing compost products to fit consumer needs. The extensive evidence of safety during production and use of composts should be of assistance to compost generators and users. But continuing research and demonstration of uses of compost products will be needed in all States and Regions in order to build improved public understanding of benefit and safety. The evidence of new markets for composts, in control of plant disease and in remediation of contaminated soils, should help others understand the unique benefits and low risk of compost products. The continuing evidence of many beneficial uses in horticulture, agriculture and landscaping help with market development. Progress in opening markets previously restricted to chemical fertilizers or virgin organics was encouraging.

Where do we go from here? In the US, cities and the private sector implement technologies such as production and marketing of compost products from the wide range of feedstocks considered at this meeting. On farm composting is an opportunity which can become important if mechanisms to permit composting facilities are developed, and if operators control product quality and nuisance problems. Private sector firms can make contracts to handle the multiple feedstocks which can be safely and beneficially built into high quality composts, providing savings to companies which would have to pay much more for disposal in landfills of by-products which can clearly add to the benefits of a compost. Remarkable public benefit is possible from adoption of the model emphasized at this Symposium for production of compost products from agricultural, municipal, and industrial by-products.

Poster Abstracts

"EVALUATION OF BENEFICIAL CO-UTILIZATION

BELTSVILLE SYMPOSIUM XXII

COMPOSTING OF WETLAND SEDIMENTS HEAVILY CONTAMINATED WITH CHLORINATED HYDROCARBON WASTES

Brad Barré and Gary Breitenbeck, Louisiana State University, Baton Rouge, LA

Remediation of contaminated wetlands require technologies that do not result in the devastation of these ecologically valuable habitats during decontamination. A study was initiated to investigate whether composting contaminated sediment with supplemental cellulosic substrates would accelerate disappearance of recalcitrant, heavily chlorinated hydrocarbons in a contaminated Louisiana swamp adjacent to the Petro-Processors, Inc Superfund site (Baton Rough, LA). Nine substrates were assessed for their ability to absorb waste and subsequently promote degradation: bagasse, kenaf, bermudagrass hay, native wetland vegetation, rice hulls, tree bark, cotton gin compost product, sawdust, and sphagnum moss. When dry, adsorption capacities ranged from 1.2 to 5.1 g/g. When water saturated, substrate mineralization rates ranged from 3.5 to 46.8 mg CO_2-C in 24 h. Forced-air column studies were performed using hay, sphagnum moss, and native vegetation. After 14d, extractable chlorinated and non-chlorinated hydrocarbons were reduced 34.0%. GC-MS analysis indicated that 59.6%, 96.8% and 40.0% of phenanthrene, hexachlorobutadiene, and hexachlorobenzene were lost, respectively. Passively aerated column studies designed to simulate a 30-cm core from a static compost pile were performed using hay. Total waste was reduced by 44.7% in 84 d primarily by conversion of waste to non-extractable forms (humification). Pilot-scale studies were conducted employing in-vessel reactors where 0.06 m^3 hay and 0.06 m^3 cotton gin trash were added to 0.03 m^3 contaminated soil (35 g hydrocarbons/kg soil). Total chlorinated and non-chlorinated hydrocarbons were reduced by 88.4% after 125 d in reactors turned three revolutions twice per week. These findings suggest that composting shows promise as a practical strategy for remediating organochlorine contaminants in the sediments of tributaries that traverse this wetland.

COMPARISON OF COMMERCIAL FERTILIZER AND ORGANIC WASTES ON SOIL CHEMICAL, PHYSICAL, AND BIOLOGICAL PROPERTIES

Michael Brosius[1], Gregory Evanylo[1], Jean Beagle Ristaino[2], and Russ Bulluck[2], [1]Department of Crop and Soil Environmental Sciences, Virginia Tech, Blacksburg, VA; [2]Department of Plant Pathology, North Carolina State University, Raleigh, NC

The success of fresh market vegetable farmers is dependent on maintaining or enhancing the quality of their soil. The objective of this project is to study the effects of conventional and alternative fertility practices on biological, chemical, and physical attributes that constitute soil quality and affect crop yield on six vegetable farms in the mid-Atlantic region. Three of the producers were long term biological farmers and three had a history of chemical weed and insect control. Two fertility treatments, a conventional treatment using commercial fertilizer at rates determined by routine soil testing and an alternative treatment using an available organic fertility source (either composted cotton gin trash, co-composted yardwaste and livestock manure, or beef manure), were employed. The alternative fertility sources were applied at rates to meet the nitrogen needs of each crop according to estimated N mineralization rates. Treatments were replicated three times in a randomized complete block. Three farms produced sweet corn and three farms produced cucurbits (cassava melon and watermelon) during the first year of the study. Soil was sampled to a depth of 0.3 m when

the melon vines began to run and at corn silking for Mehlich I-extractable P, K, Ca, Mg, Mn, Zn, Cu, and B; pH; total Kjeldahl N; NH_4-N; NO_3-N; total C; organic matter; cation exchange capacity; total P; and microbiological indicators. Immediately following harvest, soil was sampled for bulk density, water-holding capacity, aggregate stability, and the biological indicators. Fresh yield was determined by collecting and weighing all corn ears and melons from 3.6 m sections of each of two center rows from each plot. The alternative soil amendments increased soil pH, organic matter, total C, and concentrations of most nutrients above that of the commercial fertilizer. Two of the three historically organic farms had higher numbers of the beneficial soil fungi *Trichoderma* and *Gliocladium* species initially at planting than the other farms. Populations of these fungi increased over time in the three historically conventional farms and were greater at harvest in plots treated with organic than inorganic fertilizers. These results are significant because these fungal species are known antagonists of pathogenic soilborne fungi and are known biological control organisms. Populations of total bacteria and enteric bacteria did not vary greatly with location or soil amendment, even in soils amended with animal manures. Plant pathogenic oomycete fungi (*Pythium* and *Phytophthora* species) increased with time and were greater in plots treated with inorganic fertilizers than organic amendments at harvest. The most striking trends are between the historically organic and conventional farms. However, some groups of soil microorganisms (beneficial *Trichoderma*, *Gliocladium* and thermophilic microorganisms) increased within a single season in plots amended with organic amendments, which indicates that beneficial soil organisms can be increased via organic amendments. Yields were not significantly different between fertility treatments, except at one site where conventionally-fertilized corn yielded higher than that amended with yard waste compost. The lack of higher yields with the organic amendments than with the commercial fertilizer, despite the other advantages of the organic amendments, may have been due to incorrectly estimating N mineralization.

USE OF PAPERMILL AND MUNICIPAL BIOSOLIDS TO ENHANCE YIELDS OF COTTON GROWN ON A DROUGHTY SOIL

Chris Coreil and Gary Breitenbeck, Louisiana State University, Agricultural Center, Baton Rouge, LA

Field experiments were inititated to assess the effects of various organic wastes on the growth and yield of dryland cotton (*Gossypium hirsutum* L.) grown in the Macon Ridge region of Louisiana. The soil used for these experiments (Gigger-Gilbert complex) contains a shallow hard pan (40 to 50 cm deep) and is characteristic of the Macon Ridge region. Greenhouse and laboratory studies showed that the compacted, acidic hardpan and underlying subsoil contained high amounts of Al and Mn and will not support cotton development. Field experiments were performed to assess the ability of organic amendments to enhance dryland cotton production on this droughty soil. Four of the most abundant organic wastes in the Macon Ridge area (papermill sludge, papermill fly ash, municipal sewage sludge, composted sewage sludge and selected combinations of these materials) were applied alone or as mixtures as vertical mulches or as broadcast treatments. Responses to these wastes applied as vertical mulches (15-cm wide trenches filled to a depth of 50 cm) were compared to those of similar rates applied by broadcast and incorporation These experiments showed that broadcast applied sewage sludge and sewage sludge plus fly ash significantly increased yields over conventional production practices. In contrast, papermill sludge or a combination of papermill sludge and fly ash significantly reduced yields. Overall, broadcast applications were as effective as vertical mulching. Yield responses were due to combinations of factors. For sewage sludge alone and with fly ash, sustained nutrient supplying ability, net mineralization of nutrients, pH buffering properties, and increased aeration and water holding capacity may have contributed to the increased yields. In the case of papermill sludge, with and without fly ash, decreased yields may be attributed to a net immobilization of nutrients.

USE OF AMMONIATED SUGARCANE MILLING WASTE TO ENHANCE *IN SITU* DEGRADATION OF SPILLED CRUDE OIL

Bryan Grace and Gary Breitenbeck, Louisiana State University, Agriculture Center, Baton Rouge, LA

Remediation of coastal wetland ecosystems contaminated with spilled crude oil is complicated because these heavily vegetated areas typically offer limited access to cleanup equipment and personnel. Laboratory studies were performed to investigate the value of naturally occurring, N-rich materials for *in situ* remediation of oil-contaminated wetlands. Materials tested included bagasse (BG; 0.5% N), a mixture (1:1) of bagasse and cottonseed meal (CSM/BG; 3.1% N), ammoniated bagasse (ABG; 6.5%N), and ground chicken feathers (GCF; 13.2%N). Bagasse is the rind of sugarcane that remains after milling and was ammoniated by reaction with NH_3 under elevated temperature and pressure. These studies showed that some of these materials were not only excellent oil absorbents, but also greatly enhanced microbial degradation of absorbed oil. Surface application of 1 cm of N-rich organic absorbents greatly enhance hydrocarbon disappearance. Losses of oil in 90 d from contaminated marsh soil treated with ABG and GCF were 96.8% and 94.9%, respectively. Adsorbents containing lower amounts of N were less effective. The corresponding loss of oil from untreated soil was 58.2%. The most effective materials, ABG and GCF, appeared to reduce mineralization of hydrocarbons to CO_2, but significantly enhance VOC losses and conversion of contaminant oil to humic matter. The physical characteristics of ABG render this material more suitable for application to wetland environments than those of GCF. These findings suggest that surface application ABG provides an effective and economical technology to safely contain small pockets of contaminant oil distributed throughout wetland ecosystems and to promote their *in situ* degradation.

DEHYDRATION OF RESTAURANT FOOD WASTES PRODUCES A NUTRITIOUS FEEDSTUFF FOR USE IN PIG DIETS.

R. O. Myer, D. D. Johnson, K. K. Boswick, and J. H. Brendemuhl, University of Florida, Gainesville

A dehydrated food waste product (DFW) was evaluated as a potential feedstuff for pig diets. Food wastes were obtained from food service operations at a resort complex. These wastes were mostly leftover food and plate scrapings, and contained 20 to 40% dry matter (DM). The wastes were minced, blended with a feedstock (67:33 blend of soyhulls and ground corn), pelleted and dried using the Nutra-feed® protocol and equipment. Drying temperature was 150 to 200 °C (product temperature of 110 to 120 °C). Dried ground product was blended with additional minced wastes and dried; this was repeated. The final DFW product contained about 60% of the DM as dried food waste. The DFW product averaged 8.4% moisture, 16.0% crude protein, 14.4% crude fat, 14.6% crude fiber, 4.7% ash, 0.62% lysine, 0.60% threonine, 0.63% Ca, and 0.38% P. Chloride (0.86%) and Na (0.47%) were high. A feeding trial involving 72 finishing pigs (56 to 108 kg) was conducted comparing nutritionally adequate corn-soybean based diets with DFW product included at either 0, 40, or 80% of the diet. Pig growth rate and carcass lean content were not affected ($P>.10$) by the inclusion of the DFW product in the diets. Gain-to-feed improved ($P<.01$; linear) as the level of DFW increased in the diets reflecting the increase in diet energy density as the result of the high fat content of the DFW product. Meat quality characteristics and taste evaluations of broiled loin chops were not affected ($P>.10$), but carcass fat firmness decreased ($P<.01$; linear) with increasing DFW. Dehydration of food wastes can produce a nutritious feedstuff for pig diets while offering a viable solid waste disposal option.

IMMATURE COMPOST AS POTENTIAL BIOLOGICAL WEED CONTROL AGENT IN COMMERCIAL VEGATABLE PRODUCTION SYSTEMS

M. Ozores-Hampton[1], T. A. Obreza[1], P. J. Stoffella[2], D. A. Graetz[3], [1]Univ. of Florida, Southwest Florida Research and Education Center. Immokalee, FL; [2]Univ. of Florida, Indian River Research and Education Center, Ft. Pierce, FL; [3]Univ. of Florida, Gainesville, FL.

Composting municipal solid waste (MSW) and biosolids can be an attractive alternative waste management practice as the cost of landfilling increases. Compost maturity is a major issue that the composting industry is facing as it attempts to provide a high quality product to the agricultural community. The potential for using immature compost (mixture of MSW and biosolids) for weed control row middles between raised beds was evaluated. Two field experiments were conducted (Autumn 1995 and Winter 1996) with treatments consisting of 3.75 (45 $t\,ha^{-1}$), 7.5, 11.25, and 15 cm thicknesses in the Autumn and 1.85, 3.75, 7.5, and 11.25 cm thicknesses in the Winter of 4-week-old immature compost applied as a mulch, Paraquat applied at 0.56 kg/ha, and an untreated control. Weed control was evaluated for percentage weed ground cover, dominant weed species, and total weed dry weight. In the autumn experiment, with 3.75 cm of compost decreased weed germination and growth by 87% and 50% compared to the control and herbicide treatment 240 days after treatment (DAT), respectively. Compost applied at 7.5, 11.25, and 15 cm completely inhibited germination and growth of weeds for 240 DAT. In the winter trial, complete weed inhibition and growth was observed for only 65 days with the above compost thicknesses due to higher weed pressure, especially yellow nutsedge (*Cyperus esculentus*). In the winter trial, a 50 % reduction in percentage weed cover was obtained with 11.25 cm of immature compost 240 DAT compared to the control. Inhibition of germination or subsequent weed growth may be attributed to both the physical effect of the mulch and the presence of phytotoxic compounds in the immature compost. Acetic acid was present in concentrations of 1221 $mg\,kg^{-1}$ (Autumn), and 4128 $mg\,kg^{-1}$(Winter) in the 4-week-old compost. As weed growth pressure increases, thicker compost layers may be more effective for weed control, except when yellow nutsedge is the dominate weed species.

CO-COMPOSTING DAIRY MANURES WITH URBAN RESIDUES TO REDUCE VOLATILE NITROGEN LOSS AND PRODUCE A VALUE-ADDED PRODUCT

Lawrence J. Sikora, Robert Erdman and Nancy K. Enkiri, USDA-ARS, Soil Microbial System Laboratory, Beltsville, MD

Dairy operations near cities have a unique environmental setting that is both liability and benefit. One benefit is proximity to the market for their products. A liability is proximity to the sprawling suburban complex that reduces the land area where dairy manures can be applied in an environmentally sound manner. Another liability is increased incidences of odor complaints by encroaching residents around dairy operations. Odors primarily are a result of nitrogenous compounds volatilized from stored, unprocessed dairy manure. On the benefit side, dairy manure is a nitrogen source that would mix well with residues from urban operations such as tree and yard trimmings, leaves and source-separated municipal trash to make an excellent soil amendment product after undergoing the composting process.

Studies were conducted in a bench scale, self heating laboratory composter to determine techniques for reducing ammonia loss during composting. Mixtures of dairy solids and municipal refuse compost or dairy solids and basaltic rock dust were composted and ammonia and carbon dioxide evolution monitored. Addition of municipal refuse compost to dairy solids reduced ammonia evolution significantly during composting.

Rock dust stimulated decomposition of dairy manure without generating an equal, concomitant evolution of ammonia. The mechanism for stimulation is not known.

Co-composting a carbonaceous material with manure should reduce ammonia losses considerably. Resulting compost will have more N than refuse compost and will release plant available N more slowly than dairy manure alone. These characteristics add value to the final compost that neither starting ingredient possesses.

FOOD WASTE COMPOSTS WITH SLOW-RELEASE NITROGEN VALUE: THE BULKING AGENT IS MORE THAN JUST FLUFF

D. M. Sullivan[1], S. C. Fransen[2], A. I. Bary[2], and C. G. Cogger[2], [1]Oregon State Unversity, Department of Crop and Soil Science, Corvallis, OR; [2]Washington State University, Department of Crop and Soil Sciences, Puyallup, WA

Compost bulking agents do more than just provide aeration in the composting process. They also play a big role in the amount of plant-available nitrogen (N) supplied by the finished compost. We evaluated the N fertilizer replacement value of composts derived from food waste (vegetable, meat, fish, dairy, and bakery residuals). Six composts were produced with three bulking agents (yard waste, yard waste + mixed waste paper, and wood waste + sawdust), and two composting methods (aerated-static pile, and aerated-turned pile). We determined compost N fertilizer replacement value in a 3 yr. field growth trial with a perennial grass (forage-type tall fescue). We incorporated the composts at 70 dry tons/acre (about 7 yd3/1000 ft3) before grass seeding. We measured grass N uptake via harvesting every 30 to 45 days during the growing season. Finished compost N analyses were very similar to measured total N concentrations for the initial composting mixtures (1.0 to 1.8 % total N). Grass N uptake increased linearly with compost total N concentrations. Food waste composted with yard waste had the highest total N analysis and the highest fertilizer N replacement value in the second and third years of the field study (> 200 lb N/acre/yr). We recommend yard waste (1 to 1.5 % total N) as a suitable bulking agent for production of composts with significant slow-release N value. Compost bulking agents do more than just provide aeration in the composting process. They also play a big role in the amount of plant-available nitrogen (N) supplied by the finished compost. We evaluated the N fertilizer replacement value of composts derived from food waste (vegetable, meat, fish dairy, and bakery residuals). Six composts were produced with three bulking agents (yard waste, yard waste + mixed waste paper, and wood waste + sawdust), and two composting methods (aerated-static pile, and aerated-turned pile). We determined compost N fertilizer replacement value in a 3 yr. Field growth trial with a perennial grass (forage-type tall fescue). We incorporated the composts at 70 dry tons/acre (about 7 yd^3/1000 ft^3) before grass seeding. We measured grass N uptake via harvesting every 30 to 45 days during the growing season. Finished compost N analyses were very similar to measured total N concentrations (1.0 to 1.8 %) for the initial composting mixtures. Grass N uptake increased linearly with compost total N concentrations. Food waste composted with yard waste produced compost with the highest compost N analysis and the highest fertilizer N replacement value. Compost producers targeting high-value markets should use bulking agents like yard waste that supply enough N for significant slow release nitrogen value.

Session II - Tuesday, May 6

AGRONOMIC IMPACT OF HIGH RATES OF PHOSPHOGYPSUM APPLIED TO BAHIAGRASS PASTURE ON A FLORIDA SPODOSOL SOIL

I. S. Alcordo, J. E. Rechcigl, R.C. Littell, A. K. Alva, and C.E. Roessler, Institute of Food and Agricultural Sciences, University of Florida, Ona, FL

Phosphogypsum (PG), a by-product of the wet-process manufacture of phosphoric acid from phosphate rock, is primarily gypsum ($CaSO_4.2H_2O$). It is a potential source of sulfur (S) and calcium (Ca) for crops. However, because of the presence of small amounts of radionuclides, such as ^{226}Ra, the EPA has imposed severe restrictions on the use of PG. It has been demonstrated in previous studies by the authors that rates not exceeding 4 Mg PG ha^{-1} increased bahiagrass forage yields. This study extended the rates to obtain statistically measurable radiological and agronomic responses to high rates of PG so as to define these responses at the low agronomic rates. Phosphogypsum, at 0, 10, 20 Mg ha^{-1}, was applied to a Pensacola bahiagrass (Paspalum notatum Flugge) pasture on Myakka, a spodic soil. The impacts of PG were evaluated on forage yield and quality, soil, and surficial groundwater. This paper deals only with the agronomic aspects of the study.

Overall, at high rates, PG decreased regrowth dry matter (DM) yield of bahiagrass linearly (Mg DM $ha^{-1} = 5.65 - 0.44T$, where T = 10 Mg PG ha^{-1}). The ANOVA indicated treatment differences in the order of T20<T0=T10. Thus, the adverse effects of high PG rates on yield can occur initially at rates in excess of 10 Mg PG ha^{-1}. Percent Ca in forage increased linearly, defined by the equation: $\%Ca = 0.44 + 0.008T$, where T = 1.0 Mg PG ha^{-1}; %S and %Mg increased quadratically ($\%S = 0.190 + 0.047T - 0.0015T^2$ and $\%Mg = 0.296 - 0.013T + 0.0003T^2$, where T = 1.0 Mg PG ha^{-1}). Soil pH decreased linearly ($pH = 5.74 - 0.33T$) in the top 5 cm of the soil but tended to increase in the spodic layer in the order of T20>T10>T0. Soil Ca increased linearly in the top 5 cm layer (mg Ca $kg^{-1} = 1102 + 63T$; T = 1.0 Mg PG ha^{-1}), in the 15-30 cm layer (mg Ca $kg^{-1} = 117 + 3T$; T = 1.0 Mg PG ha^{-1}), and in the spodic (mg Ca $kg^{-1} = 78 + 2T$; T = 1.0 Mg PG ha^{-1}). Soil Mg decreased in the top 5 cm (mg Mg $kg^{-1} = 114.07 - 11.76T + 0.38T^2$) and in the 15-30 cm layers (mg Mg kg $ha^{-1} = 0.309 - 0.01T + 0.0003T^2$). Subsurface waters collected down to 45 and 90 cm indicated reductions in pH and increases in electrical conductivity with PG rates. The study showed PG to be an effective source of Ca and S for bahiagrass pastures. So as to avoid adverse effects on forage yield, PG should be applied at rates less than 10 Mg PG ha. Based on the results of earlier studies conducted by the authors, the best PG rates to enhance yield ranged from 0.4 to 1.0 Mg PG ha^{-1} applied annually or from 2 to 4 Mg PG ha $^{-1}$ applied once every three years.

SOIL REMINERALIZATION FOR SUSTAINABLE VEGETABLE PRODUCTION

Joanna Campe[1], Tara A. O'Brien[2] and Allen V. Barker[2], [1]Remineralize the Earth, Inc., Northampton, MA; [2]University of Massachusetts, Amherst, MA

Dusts from washed glacial moraines or finely ground hard silicate rocks contain a broad spectrum of mineral elements beneficial for plant growth. Soil remineralization is the utilization of these dusts to restore soil fertility through replenishment of plant nutrients removed by agricultural activities or by forces of nature. Research was initiated in 1996 to assess remineralization of soils in an established organic mixed vegetable

crop production system at the Smith Vocational School in Northampton, Mass. Basalt rock dust from a quarry in Amherst, Mass., was evaluated for romaine lettuce (Lactuca sativa longifolia Lam.) production. Regimes of soil fertility included treatments of (1) a mixed organic fertilizer (4% N-2% P-3% K), (2) food waste compost applied at 20 tons/acre, and (3) the compost with basalt dust (400-mesh) applied at 4 tons/acre. Four sequential lettuce crops of 4 or 5 weeks duration from planting to harvest were grown in randomized complete blocks. Compared with the organic fertilizer treatment or with compost alone, remineralization elevated concentrations of available P, K, Ca, and Mg at planting and at harvest. None of the treatments affected availabilities of nonessential elements, Pb, Cd, Cr, and Al, indicating no polluting effects from the rock dusts or compost. Soil acidity was decreased significantly by the addition of rock dust with compost, which also lowered soil acidity relative to the organic fertilizer. Benefits of rock dust and compost in maintaining or enhancing soil organic matter were apparent. Head yield of lettuce did not differ significantly among treatments. Chemical analyses of the bottom leaves after trimming indicated that all treatments produced heads with adequate concentrations of macronutrients and micronutrients without significant differences among treatments. The results support remineralization as a means of sustaining soil fertility by elevating levels of available plant nutrients in soil.

THE INFLUENCE OF SILICATES ON THE AVAILABILITY OF PHOSPHATES

Sam Catalano, Pacific Mineral Development PTY LTD, Innisfail, Queensland, Australia

Rising costs and impoverished soil make it difficult for tropical countries to increase food production. Agriculturalists, while adding the major nutrients N, P, and K in the form of commercially available fertilizer usually ignore the need to replenish minor nutrients and trace elements in highly leached tropical soils. Our work has centered on the use of quarry wastes that contain the necessary nutrients and trace elements, and allows nature to do the rest.

Fine ground volcanic rock, 90% passing 150 micron, was applied as a source of available silicaon to sugar cane and bananas on Kranazem soils in Northern Australia. The purpose of the experiment was to evaluate the performance of three applications on yield and insect resistance. Rock dust was applied at 1.5, 2.5 and 5 tonnes per hectare.

Whilst tonne of cane were marginally reduced with the application of rock dust the CCS (cane content of sugar) was increased due to the more erect nature of the sugar cane crop. The rock dust reduced root diseases in bananas thus significantly increasing production due to the reduced fall out in plants

COAL COMBUSTION BY-PRODUCTS ASSOCIATED WITH COAL MINING INTERACTIVE FORUM

Dr. Yoginder (Paul) Chugh[1], Brandi Sangunett[1],[2]Kimery C. Vories [1]Mining Engineering Department, Southern Illinois University, Carbondale, IL, [2]USDI Office of Surface Mining, Alton, IL

A series of 28 papers summarizing topics related to coal combustion by-products and their application at surface coal mines nationwide were presented. Topics include activities related to beneficial use and disposal. The papers are presented by university researchers, state regulatory personnel, industry experts, consultants, and citizen interest groups. The papers are presented in the categories of: (1) Coal Combustion By-Product Characterization; (2) Site Characterization; (3) Regulatory Requirements; (4) Designing/Engineering/Planning; (5) Environment: Land and Water; (6) Monitoring and Evaluation; and

(7) Case Studies. An edited discussion section provides a summary of the issues raised, different prospectives, and controversies brought out during the forum. The results of subject category workgroups at the forum outline remaining issues needing further work and attention.

EFFECT OF SURFACE INCORPORATED COAL COMBUSTION BY-PRODUCTS ON EXCHANGEABLE Ca AND Al IN SUBSOIL

Urszula Kukier[1], William P. Miller[2] and Malcolm E. Sumner[2], [1]Institute of Soil Science and Plant Cultivation, Pulawy, Poland, [2]University of Georgia, Athens, GA

Gypsum has various beneficial effects on soil physical and chemical properties. Amelioration of subsoil acidity is one of the most important effects. Acid subsoils contain usually low levels of Ca and high levels of Al. Aluminum toxicity and/or low Ca saturation affect root proliferation in the subsoil. As a result roots are not able to extract nutrients and water from deeper soil layers and the crop is less resistant to droughts occurring during the growing season. Mined gypsum is applied on commercial basis to alfalfa and peanut in the South-Eastern states of US. Recently, it is being substituted by industrial by-product gypsum materials. Modern flue gas desulfurization technologies based on a forced oxidation of SO_2 result in production of wallboard quality gypsum by-product (FDG).

The effect of FDG applied as single component and in a mixture with fly ash on soil exchangeable Ca, Al, Mg and plant available B was studied in a field experiment conducted on a fine mixed thermic Vertic Paleaquult. The FDG material was applied alone and in a 1:1 mixture with fly ash at rates of 0, 5, 10 and 20 Mg/ha. Treatments were surface broadcasted and mixed with the 0-20 cm soil layer. Each treatment had three replications. Soybeans were planted in the first growing season followed by corn in the second season. Soil cores were collected from the experimental plots to depth of 80 cm in July of 1994 about 16 months after treatment application. Cores were segmented into 10 cm increments. Exchangeable Ca and Mg in soil samples were determined in 1M NH_4OAc extracts. Exchangeable Al was extracted in 1 M KCl. Cations in supernatants were determined by atomic absorption spectrometry. Hot water soluble boron was measured only in soil samples collected from control plots and plots amended with 20 Mg/ha rate of coal combustion by-products.

Application of FDG increased exchangeable Ca and decreased exchangeable Al to various depths depending on the rate applied. Losses of exchangeable Mg from the upper soil layer were observed at all application rates. Soil boron deficiency in the 0-20 cm layer was alleviated by application of 20 Mg/ha of the fly ash-FDG mixture.

THE EFFECT OF POWDERED ROCK ON GROWTH AND MINERAL CONTENT OF VEGETABLES

David H. Miller, Oberlin College, Biology Department, Oberlin, Ohio

We are testing the potential for powdered rock to serve as a source for mineral nutrients for plants grown on soils supplemented with the powders. Vast quantities of these powders are currently stockpiled at most quarries and little economic use for them has yet to be found. We believe they have potential as a component of a more sustainable agriculture, since their mineral nutrients will only be released by weathering action as they are needed and will consequently not cause localized overabundance of any nutrient nor will their nutrients cause contamination of ground or stream waters.

Potatoes grown on soil test plots for eight and nine consecutive years have been monitored for their yields and their mineral content. While total mineral content of the crops in any one year shows only marginal increases in powdered plots, when yields are factored in, the total amount of minerals harvested with each successive crop showed a clear increase of many of the powder-augmented plots.

Pot tests using some of the same powders also showed some increases in foliar mineral nutrients of *Brassica campestris*, var. *chinensis* 'Mei Qing Choi', as well as in soil test plots supplemented with these powders.

While rates of mineralization of nutrients from these powders seem slow and will likely require long-term longitudinal studies to adequately document their effects on soil fertility, the powders clearly stimulate rates of organic carbon decomposition in both soil plots and pot tests, suggesting that they can act as available sources of mineral nutrients which stimulate the growth of soil microorganisms.

Further, we are working with a common soil mold, *Aspergillus niger*, growing it on defined nutrient media, from which specific micronutrients are withheld. When traces (5 milligram) of these rock powders are added to the deficient media, the growth and development of the mold is greatly enhanced, indicating that the mold can tap these rock powders as sources of the missing nutrient element.

NITROGEN RECOVERY BY BAHIAGRASS RECEIVING VARYING APPLICATION RATES OF PELLETIZED BIOSOLIDS

Rosa M. Muchovej[1] and J.E. Rechcigl[2], [1]University of Florida, Southwest Florida REC, Immokalee, FL, [2]University of Florida, Range Cattle REC, Ona, FL

Nitrogen fertilization has been shown to increase biomass and quality of bahiagrass (*Paspalum notatum* Flugge) dramatically in Florida sandy soils. Nevertheless, with low cattle prices, ranchers are forced to reduce production costs and fertilizers are among the top cuts. Residuals such as biosolids contain considerable amounts of N and constitute a relatively inexpensive source of the nutrient, when compared with commercial fertilizers. Determination of appropriate application rates so as to not exceed crop assimilative capabilities is important to prevent losses to the environment. The objective of this study was to investigate temporal N recovery by bahiagrass pastures from several rates of pelletized municipal biosolids. Treatments consisted of 7 rates (0, 0.25, 0.5, 1.0, 2.0, 4.0, and 8.0 Tons/acre) of biosolids. These rates provided 0, 22.5, 45, 90, 180, 360, and 720 lbs N/acre (organic and inorganic), respectively. Treatments were surface-applied on 20 ft x 10 ft plots and were arranged in a randomized complete block design, with 4 replications. In addition to the absolute control (0 lb biosolids/acre), control plots were established which received chemical forms of N [$(NH_4)_2SO_4$ or NH_4NO_3 at 160 lbs N/acre). Phosphorus and K were applied at the same rate to all plots, as Triple Superphosphate and KCl, respectively. Bahiagrass forage was harvested periodically (at 35, 69, 104, 151, and 201 days after initial application) for yield and total Kjeldahl N determinations. Nitrogen accumulation in the forage was calculated by multiplication of yield by nitrogen concentration from each plot at each harvest date. The amount of nitrogen recovered in the forage was obtained by subtracting the values obtained in the forage from the control plots (which received no external N source other than what the soil was able to provide) from those contained in the forage from the amended plots. The percentage recovery was calculated upon comparison of these values for N recovered in the forage against the amount of N added in the various amendments (biosolids or soluble fertilizers). Bahiagrass forage yields increased in a linear fashion with increasing rates of biosolids in all harvests. Nitrogen concentration and accumulation were increased to values above those obtained with the soluble N sources, especially with the higher rates of biosolids. Nitrogen recovery rates reached values higher than 75% for the lowest biosolids rate. Increasing rates resulted in greater N concentration and accumulation in the forage, but comparatively lower recovery rates were verified.

Recovery rates, in percentage of total N applied, decreased at each subsequent harvest. Averaged over all treatments, more than 50% of the N contained in the biosolids was recovered in the plant tops and most of this N was removed within the first 35 days after application.

LOSS OF PLANT NUTRIENTS DURING WINDROW COMPOSTING OF VARIOUS FEEDSTOCKS

David Schellinger and Gary Breitenbeck, Louisianna State University Agricultural Center, Baton Rouge, LA

The economic viability of composting as an alternative method of disposal of municipal, industrial and agricultural wastes is dependent on the development of practical beneficial uses of finished compost. The ability of finished composts to supply crops with essential nutrients is a significant factor affecting their value in production agriculture. Volatile losses of ammonia commonly observed during composting suggest that this process may result in significant losses of essential nutrients. The principal objective of this study was to assess losses of N, P, K and other plant nutrients during windrow composting of various feedstocks. Nine windrows (approximately 15 x 3 x 16 m) were constructed using eight feedstocks comprised of municipal and agricultural processing wastes. Windrows were turned weekly during the first 5-6 weeks and less frequently thereafter. Composting was terminated at 140 days. After each turning, windrows were sampled and the elemental composition of the composting material determined. Assuming that mineral matter was conserved during composting , the change in total nutrient content was determined by calculating the change in nutrient concentrations relative to ash content. These analyses showed that composting most feedstocks resulted in substantial losses of N, P and K. Nitrogen losses ranged from 0% to 65%, P losses ranged from 7% to 70%, and K losses ranged from 2% to 78%. Nutrient losses from windrows comprised of nutrient-rich, easily decomposed plant material were much larger than from those comprised of more recalcitrant material containing appreciable amounts of mineral matter. These findings suggest that composting practices can be devised to conserve plant nutrients and thereby enhance the value of composts in production agriculture.

RECOVERY OF BIOSOLIDS-APPLIED HEAVY METALS SIXTEEN YEARS AFTER APPLICATION

J.J. Sloan, R.H. Dowdy, and M.S. Dolan, USDA-ARS and University of Minnesota, St. Paul, MN.

Land application of biosolids can significantly increase heavy metal concentrations in agricultural soils. In a typical agricultural landscape with little or no slope, the major portion of biosolids applied heavy metals remain near the soil surface in the zone of incorporation with small losses due to leaching and crop removal. However, extraction of heavy metals from soils more than ten years after biosolids applications frequently accounts for less than 70% of biosolids-derived heavy metals. Clearly, more work is needed to determine the long-term fate of biosolids-applied heavy metals. The objective of this study was to quantify movement and recovery of biosolids-applied heavy metals in the profile of a well-drained Waukegan soil (fine-silty over sandy or sandy-skeletal, mixed, mesic, Typic Hapludoll). Three annual applications of biosolids from 1977-79 resulted in cumulative biosolids loadings of 0, 60, 120, and 180 Mg ha^{-1}. Cumulative heavy metal loadings for the 180 Mg ha^{-1} biosolids rate were 25, 141, 127, 43, 173, and 348 kg ha^{-1} for Cd, Cr, Cu, Ni, Pb, and Zn, respectively. Three soil cores were collected from each 0.22 ha plot using a 5-cm diameter hydraulic probe. Soil cores were segmented into 0.15 m increments to a depth of 0.9 m and corresponding increments from each core were combined. Soils were air-dried, ground to pass a 2 mm sieve, and homogenized. Soil samples from

each plot were extracted for 20 h with 1 M HNO_3 (5 g:20 mL soil:solution). Metals (Cd, Cr, Cu, Ni, Pb, and Zn) were determined in the supernatants by ICP-AES. Concentrations of 1 M HNO_3 extractable Cd, Cr, Cu, Ni, Pb, and Zn in biosolids-treated soils were much higher than the control to a depth of 0.30 m ($p<0.01$) and slightly higher at 0.30-0.45 m ($p<0.05$). There was no difference in soil metal concentrations between control and biosolids-treated soils below 0.45 m. Soil metal concentrations were converted to metal loadings (kg ha^{-1}) by using previously-determined bulk densities for Waukegan soil. Recovery of biosolids-applied heavy metals was calculated by subtracting control values from the biosolids-treated values for each depth, summing all depth increments to a depth of 0.6 m, and dividing by the biosolids-applied metal loadings. For the 180 Mg ha^{-1} biosolids loading, percent recoveries ±1 standard deviation for Cd, Cr, Cu, Ni, Pb, and Zn were 112±21, 59±18, 119±26, 114±7, 102±30, and 97±19%, respectively. Percent recoveries for the 60 and 120 Mg ha^{-1} biosolids loadings were slightly lower. These results suggest that biosolids-applied heavy metals are relatively immobile in soil and remain near the zone of incorporation.

LIST OF SYMPOSIUM PRESENTERS AND ORGANIZERS

Dr. I. S. Alcordo
University of Florida
Institute of Food and Agric. Sci.
Ona, FL 33865
ph: 941-735-1314
fx: 941-735-1930
e-mail: ona@gnv.ifas.ufl.edu

Dr. J. Scott Angle
Assoc. Dean Agr. Expt. Sta.
Professor of Soil Microbiology
Dept. Nat. Res. & Landscape Arch.
University of Maryland
College Park, MD 20742
ph: 301-405-2462
fx: 301-405-9089
e-mail: ja35@umail.umd.edu

Allen V. Barker
University of Massachusetts
Bowditch Hall
Amherst, MA 01003
ph: 413-545-4733
fx: 413-545-0260

Brad Barré
Louisiana State University
104 M. Sturgis Hall
Baton Rouge, LA 70803-2110
ph: 504-388-1362
fx: 504-388-1403

Dr. Robert K. Bastian
US EPA
Office of Wastewater Mgt. (4204)
401 M Street, SW
Washington, D. C. 20460
ph: 202-260-7378
fx: 202-260-1827
e-mail:
bastian.robert@epamail.epa.gov

Gary A. Breitenbeck
Louisiana State University
104 M. Sturgis Hall
Baton Rouge, LA 70803-2110
ph: 504-388-1362
fx: 504-388-1403
e-mail: gbreite@unix1.sncc.lsu.edu

Dr. Kirk W. Brown
Dept. of Soil and Crop Sciences
Texas A&M University
College Station, TX 77843
ph: 409-485-3603
fx:409-862-2604
e-mail:brown@tamu.edu

Dr. Sally Brown
USDA-ARS
Environ. Chemistry Laboratory
B-007, Rm. 224, BARC-W
Beltsville, MD 20705
ph: 301-504-6511
fx: 301-504-5048
e-mail: sbrown@asrr.arsusda.gov

Mr. Charles Cannon
Composting Council
114 S. Pitt Street
Alexandria, VA 22314
ph: 703-739-2401
fx: 703-739-2407
e-mail: comcouncil@aol.com

Joanna Campe
Remineralize the Earth, Inc.
Northhampton, MA 01060-4021

Sam Catalano
Pacific Mineral Development PTY LTD
Innisfail, Queensland, Australia
e-mail:
mineral@internetnorth.com.au

Dr. Rufus Chaney
USDA-ARS
Environ. Chemistry Laboratory
B-007, Rm. 224, BARC-W
Beltsville, MD 20705
ph: 301-504-6511
fx: 301-504-5048
e-mail: rchaney@asrr.arsusda.gov

Dr. Yoginder (Paul) Chugh
Southern Illinois University
Mining Engineering Department
Carbondale, IL

Dr. Michael A. Cole
Dept. of Nat. Resources Environ. Sci., University of Illinois - UC
1102 South Goodwin Avenue
Urbana, IL 61801
ph: 217-244-5154
fx: 217-333-4251
e-mail:mcole@ux1.cso.uiuc.edu

Chris Coreil
Louisiana State University
104 M. Sturgis Hall
Baton Rouge, LA 70803-2110
ph: 504-388-1362
fx: 504-388-1403

Dr. Elliot Epstein
E&A Environmental Consultants
95 Washington Street
Canton, MA 02021

Dr. Gregory Evanylo
Virginia Tech University
Dept. Crop and Soil Environ. Sci.
Blacksburg, VA 24061-0404
ph: 540-231-9730
fx: 540-231-3075
e-mail: gevanylo@vt.edu

Mr. Frank Franciosi
RT Soil Sciences
101 Fountain Park Drive
P. O. Box 1179
Rocky Mount, NC 27802
ph: 919-212-8220
fx: 919-212-8220
e-mail: FF22@aol.com

Ms. Nora Goldstein
BioCycle
419 State Avenue
Emmaus, PA 18049
ph: 610-967-4135
e-mail:BioCycle@ad.com

Dr. John Gilmour
Department of Agronomy
University of Arkansas
Fayetteville, AR 72701
e-mail: gilmour@comp.uark.edu
ph: 501-575-2354
fx: 501-575-7465

Dr. Frank R. Gouin
Upakrik Farm
420 East Bay Front Road
Deale, MD 20751
ph: 301-261-5802
fx: 410-867-1539
e-mail:
_R-GOUIN@umail.umd.edu(fg7)

Bryan Grace
Louisiana State University
104 M. Sturgis Hall
Baton Rouge, LA 70803-2110
ph: 504-388-1362
fx: 504-388-1403

Dr. Rosalie Green
US EPA, Mail Stop 5306 W
401 M Street, SW
Washington, D. C. 20460
ph: 703-368-2956
fx: 703-368-8686
e-mail:
green.rosalie@epamail.epa.gov

Dr. Yitzhak Hadar
Department of Biological Sciences
University of Waikato
P. O. Box 3105
Hamilton, New Zealand
ph: 64-7-838-4029
fx: 64-7-838-4324
e-mail: yhadar@waikato.ac.nz

Dr. Charles Henry
School of Forest Resources, AR-10
University of Washington
Seattle, WA 98195
ph: 206-685-1915
e-mail: clh@u.washington.edu

Dr. Albert E. Herner
USDA-ARS
Environ. Chemistry Laboratory
Bldg. 001, Rm. 221, BARC-W
Beltsville, MD 20705
(301)-504-8902
(301)-504-5048

Dr. Harry Hoitink
Department of Plant Pathology
Ohio State University
Ohio Agric. Res. and Devel. Center
1680 Madison Avenue
Wooster, Ohio 44691
phone 330-263-3848
FAX 330-263-3841

Dr. Lee W. Jacobs
Depr. of Crop & Soil Sciences
Michigan State University
East Lansing, MI 48824
e-mail:lee.jacobs@ssc.msu.edu

Ms. Kathy Kellogg
Kellogg Supply, Inc.
350 W. Sepulveda Boulevard
Carson, CA 90745
ph: 310-830-2200
fx: 310-835-6174
e-mail: kellsup@earthlink.net

Dr. Ronald F. Korcak
USDA-ARS
Plant Sciences Institute
B-003, Rm. 232, BARC-W
Beltsville, MD 20705
ph: 301-504-6591
fx: 301-504-5521
e-mail: rkorcak@asrr.arsusda.gov

Dr. Urszula Kukier
Institute of Soil Science and Plant
Cultivation
Pulawy, Poland

Dr. Phil Leege
Procter & Gamble Company
Winton Hill Technical Center
6100 Center Hill Avenue
Cincinnati, OH 45224-1788
ph: 513-634-6876
fx: 513-634-1434
e-mail: leege.pb@pg.com

Mr. Christopher Lufkin
Kamps Wood Resource
2900 Peach Ridge, NW
Grand Rapids, MI 49504
ph: 616-453-1986
fx: 616-453-4373

Dr. Margaret Maxey
Murchison Chair of Free Enterprise
University of Texas at Austin
Department of Engineering
Petroleum/CPE 3.168
Austin. TX 78712
ph: 512-471-7501
fx: 512-471-5120

Dr. Laura L. McConnell
USDA-ARS
Environ. Chemistry Laboratory
Bldg. 007, Rm. 225
Beltsville, MD 20705
(301)-504-6298
(301)-504-5048
e-mail: mcconnel@asrr.arsusda.gov

Dr. David H. Miller
Oberlin College
Department of Biology
130 West Lorain St.
Oberlin, OH 44074-1082
ph: 216-775-8315
fx: 216-775-8960

Dr. Robert O. Myer
University of Florida
Institute of Food and Agric. Sci.
3925 Highway 71
Marianna, FL 32446
ph: 904-482-9904
fx: 904-982-9917

Dr. Patricia Millner
USDA-ARS
Soil Microbial Systems Laboratory
Bldg. 001, Rm 140 BARC-W
Beltsville, MD 20705
ph: 301-504-8163
fx: 301-504-8370
e-mail: pmillner@asrr.arsusda.gov

Dr. Rosa M. Muchovej
University of Florida
SW Florida REC
PO Box 5127
Immokalee, FL 33912

Mr. Patrick Nicholson
NVIRO International
3450 West Central Ave., Suite 328
Toledo, OH 43603
ph: 419-535-6374
fx: 419-535-7008

Dr. Lloyd D. Norton
USDA-ARS
National Soil Erosion Lab.
Purdue University Soil Building
West Lafayette, IN 47907
ph: 765-494-8682
e-mail:norton@ecn.purdue.edu

Dr. George A. O'Connor
Department of Soil Science
University of Florida
Gainesville, FL 32611
ph:352-392-7181
fx: 352-392-3399
e-mail: gao@gnv.ifas.ufl.edu

Dr. M. Ozores-Hampton
University of Florida
SW Florida Res. And Edu. Center
PO Drawer 5127
Immokalee, FL 33934
ph: 941-657-5221
fx: 941-657-5224
e-mail:
ozores@nerum.nerdc.ufl.edu

Dr. Jack Rechcigl
University of Florida
Range Cattle Research Center
3401 Experiment Station
Ona, Florida 33865
ph: 941-735-1314
fx: 941-735-1930
e-mail: rechcigl@gnv.ifas.ufl.edu

Sally Reynolds
USDA-ARS
Soil Microbial Systems Laboratory
Bldg. 001 BARC-W
Beltsville, MD 20705
ph: 301-504-6317
fx: 301-504-8370

Dr. Dale Ritchey
ASWCRL, USDA-ARS
P. O. Box 400
Airport Road
Beaver, WV 25813
ph: 304-256-2855
fx: 304-256-2921
e-mail: dritchey@asrr.arsusda.gov

Dr. A. R. Bob Rubin
North Carolina State Univ. - BAE
Box 7625
Raleigh, North Carolina 27695
ph: 919-515-6791
fx: 919-515-6772

Dr. James A. Ryan
US EPA
National Risk Mgt. Res. Lab.
5995 Center Hill Road
Cincinnati, OH 45224
ph: 513-569-7653
e-mail ryan.jim@epamail.epa.gov

David Schellinger
Louisiana State University
104 M. Sturgis Hall
Baton Rouge, LA 70803-2110
ph: 504-388-1362
fx: 504-388-1403

Charlotte Schomburg
USDA-ARS
Environ. Chemistry Laboratory
Bldg. 007, Rm. 214 BARC-W
Beltsville, MD 20705
(301)-504-6524
(301)-504-5048
e-mail: schombrg@asrr.arsusda.gov

Mr. Bill Seekins
Maine Dept. of Agriculture
2800 Statehouse Station
Augusta, ME 04333
ph: 207-287-7531
fx: 207-287-7548
e-mail: bill.seekins@state.me.us

Dr. Aziz Shiralipour
Center for Biomass Programs
IFAS, 130 Newins-Ziegler Hall
P. O. Box 110415, U. of Fla.
Gainesville, FL 32611-0415
ph: 352-392-1511
fx: 352-392-2389
e-mail: shirali@gnv.ifas.ufl.edu

Dr. Lawrence Sikora
USDA-ARS
Soil Microbial Systems Laborator
Bldg. 001, Rm. 119 BARC-W
Beltsville, MD 20705
ph: 301-504-8163
fx: 301-504-8370
e-mail: lsikora@asrr.arsusda.gov

Dr. Regis R. Simard
Agriculture Canada
2560 Hochelaga Blvd.
Saint-Foy, Quebec GIV 2J3,
Canada
ph: 418-657-7890 ext 271
e-mail: simardr@em.agr.ca

Mr. Conrad Skimina
Monrovia Nurseries
Azusa, CA 91702-1385
ph: 818-334-9321
fx: 818-334-3126
e-mail: d_merhaut@lightside.com

Dr. John J. Sloan
University of Minnesota
439 Borlaug Hall
1991 Upper Buford Circle
St. Paul, MN 55108

Dr. Robin A. K. Szmidt
Horticultural Advisory Service
SAC,
Auchincruive, Scotland, UK KA6 5HW
ph: 44-1292-525390
fx: 44-1292-525389
e-mail: SZM@au.sac.ac.uk

Dr. Richard Stehouwer
OARDC
School of Natural Resources
1680 Madison Avenue
Wooster, OH 44691-6900
ph: 330-263-3655
fx: 330-263-3658
e-mail: Stehouwer.1@osu.edu

Dr. Dan M. Sullivan
Oregon State University
Dept. Crop and Soil Science
Corvallis, OR
ph: 541-737-5715
e-mail: sullivad@css.orst.edu

Dr. Cecil Tester
USDA-ARS
Soil Microbial Systems Laboratory
Bldg. 001, Rm. 140 BARC-W
Beltsville, MD 20705
ph: 301-504-9386
fx: 301-504-8370

Dr. John M. Walker
US EPA, Mail Stop 4204
400 M Street, S. W.
Washington, D. C. 20460
ph: 202-260-7283
fx: 202-260-0116
e-mail:
walker.john@epamail.epa.gov

Dr. Robert J. Wright
USDA-ARS
Environ. Chemistry Laboratory
Bldg. 001, Rm. 226 BARC-W
Beltsville, MD 20705
ph: (301)-504-5443
fx:: (301)-504-5048
e-mail: rwright@asrr.arsusda.gov

Dr. Kimery C. Vories
USDI-Office of Surface Mining
Reclamation and Enforcement
Alton Federal Building
501 Belle St.
Alton, IL 62002

NOTES

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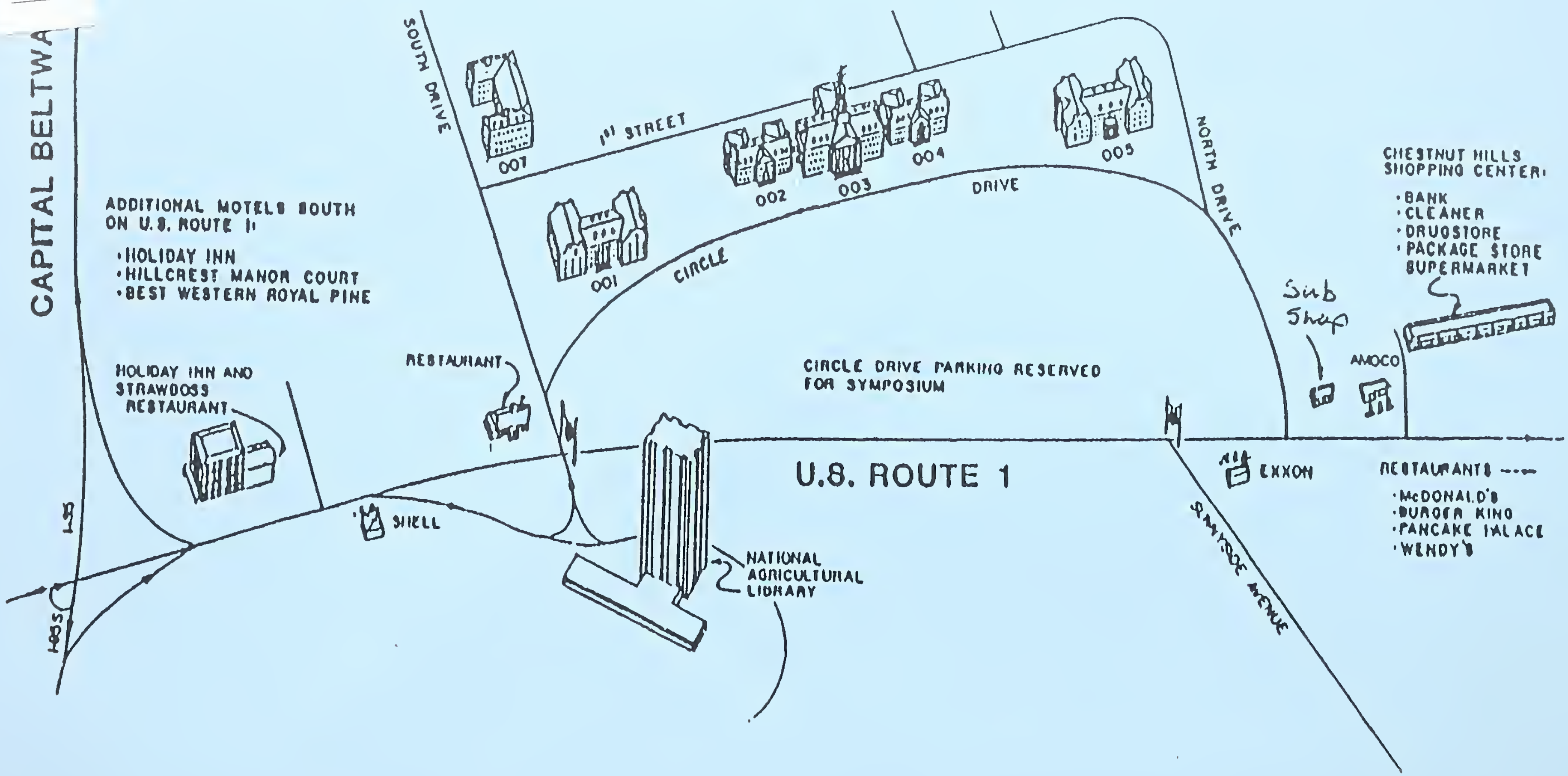
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